OAIP

Ontario
Assessment
Instrument
Pool

Physics

INTRODUCTION

SENIOR DIVISION

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Ministry of Education
Ontario

Hon. Bette Stephenson, M.D., Minister
Harry K. Fisher, Deputy Minister

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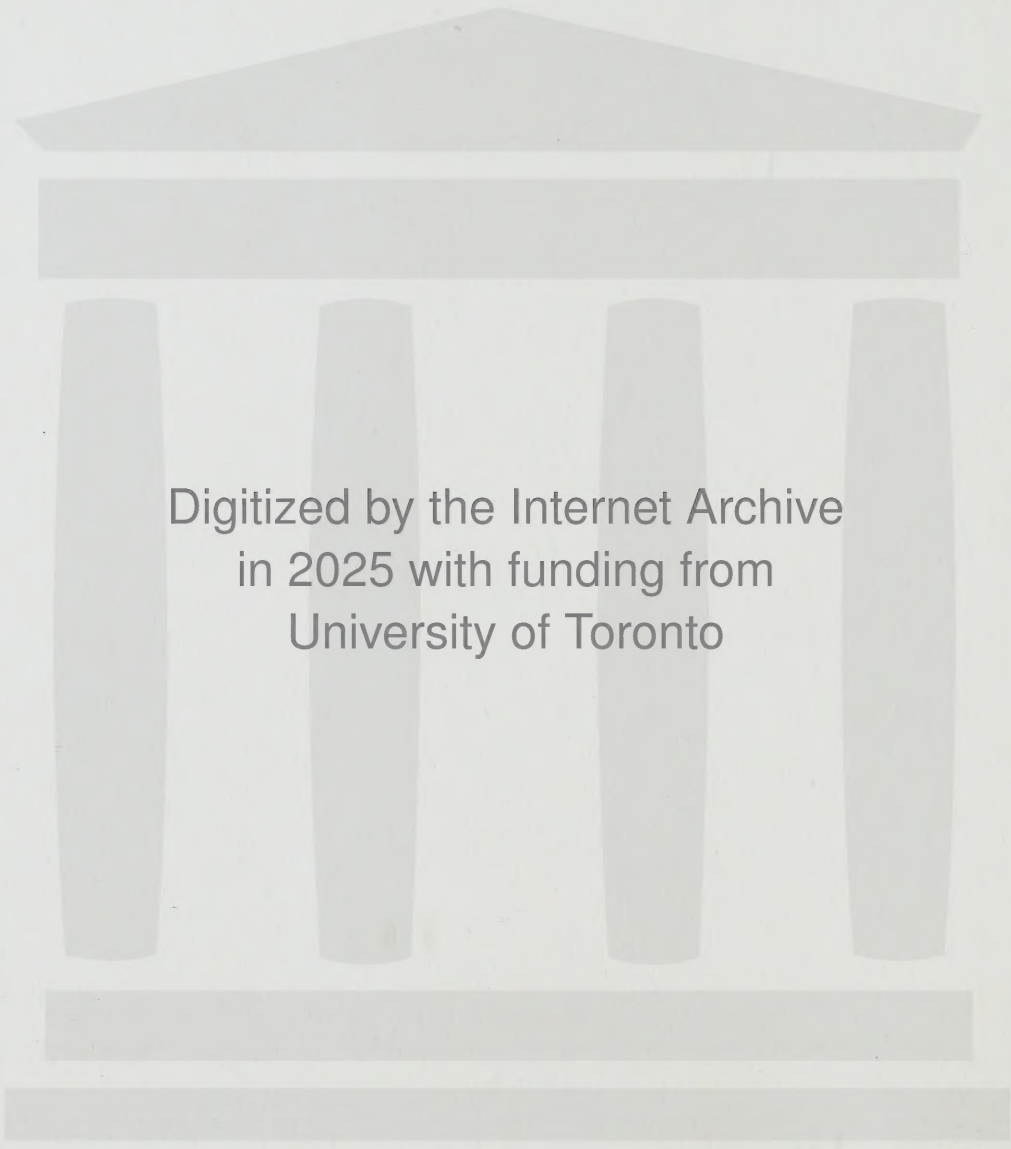
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TO THE RECIPIENT

The attached package is a replacement for pages 1-28 of the Ontario Assessment Instrument Pool, Physics, Senior Division, which was published in 1981.

PHYSICS: INTRODUCTION

SENIOR DIVISION

THE ONTARIO ASSESSMENT INSTRUMENT POOL

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This package contains the introduction and the objectives for the assessment materials relating to the aims, goals, and objectives of Senior Division Physics as implied in the Ontario Ministry of Education Curriculum guidelines for physics in the Senior Division. Additional materials will be distributed as they become available. It is also anticipated that materials presently in the pool will be revised as new curriculum guidelines become available.

Cost: $15.00

Copies of this package may be obtained from:

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Toronto, Ontario
M7A 1N8

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M7A 1N8

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Toronto, Ontario
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Test Instrument Topics and Their Symbols

	Symbol
Measurement	M
Functions	F
Kinematics	K
Motion in a Straight Line	K-MSL
Motion in a Plane and Vectors	K-MPV
Dynamics	D
Force and Newton's Laws	D-FNL
Centripetal Force and Gravitation	D-CFG
Impulse and Conservation of Momentum	D-ICM
Work and Kinetic Energy	D-WKE
Gravitational Potential Energy	D-GPE
Behaviour of Light and Models of Light	L
Geometric Optics (See also Ray or Geometric Optics.)	L-GO
Particle Model of Light	L-PML
Characteristics and Behaviours of Waves	L-CBW
Interference of Periodic Waves	L-IPW
Wave Model of Light and Interference	L-WML
Electricity and Magnetism	EM
Electric Forces and Charges	EM-EFC
Electric Field and Potential	EM-EFP
Current Electricity and Electromagnetism (See also Electromagnetism.)	EM-CEE
Electromagnetic Spectrum	EM-ES
Wave-Particle Duality of Electromagnetic Radiation and Matter	WPD
Photons	WPD-P
Matter Waves	WPD-MW
The Atom	A
The Rutherford Model	A-RM
Energy Levels	A-EL
Nuclear Energy	NE

	Symbol
Sound	S
The Nature of Sound	S-NS
Music	S-M
Noise	S-N
The Ear	S-E
Electromagnetism (See also Electricity and Magnetism.)	E
Magnets	E-M
Electromagnets	E-E
Applications	E-A
Basic Electronics	BE
The p-n Junction	BE-p-n
The Diode	BE-D
The MOSFET Transistor	BE-MT
The Zener Diode	BE-ZD
Ray or Geometric Optics (See also Behaviour of Light and Models of Light.)	GO
Sources and Travel	GO-ST
Reflection	GO-R
Refraction	GO-Rfra
Optical Instruments	GO-OI
Colour	C
The Spectrum	C-S
Colour and Colour-Mixing	C-M
Colour Vision	C-CV
Infrared and Ultraviolet Radiation	C-IUV
Fluids	Fl
Fluids at Rest	Fl-R
Fluids in Motion	Fl-M

	Symbol
Thermal Effects	T
Temperature	T-T
Heat	T-H
Thermal Expansion	T-E
Calorimetry	T-C
Evaporation	T-E
First Law of Thermodynamics	T-L
Statics	ST
Torque and Equilibrium	ST-TE
Machines	ST-M
Radioactivity and Radiation Exposure	R
Radioactivity	R-R
Radiation Exposure	R-RE
Energy Sources and Conservation	ES
Energy Sources	ES-S
Energy Conservation	ES-C
Historical Perspective - Astronomy	HA
The Universe	HA-U
Greek Scientists	HA-GS
Copernicus and Brahe	HA-C&B
Kepler	HA-K
Galileo	HA-G
Newton and Beyond	HA-N

Introduction

The purpose of this Ontario Assessment Instrument Pool is to provide a variety of assessment instruments designed to meet the aims, goals, and objectives of Senior Division Physics as stated or implied in the Ontario Ministry of Education Curriculum guidelines.

Background information about the creation of the Ontario Assessment Instrument Pool (OAIP), as well as information about other programs and courses for which assessment instruments have been developed, may be found in the ministry's publication Ontario Assessment Instrument Pool: A General Introduction (Toronto: Ministry of Education, Ontario, 1980).

Variety of Assessment Instruments

As used here, the term assessment instrument refers to the smallest unit of the physics pool that can be used by teachers to evaluate students' achievement of a specific objective. The objectives of physics are many and varied. Some objectives specify the knowledge component of physics; others, the processes of scientific inquiry; others, the skills and techniques specific to the use of scientific equipment; others, technological applications in the physical world; and still others, the attitudes and values that permeate the scientific enterprise.

Assessment instruments are needed to assist teachers in evaluating student progress towards the various goals and objectives of physics courses in the secondary school. For this reason, the pool, as it develops, will consist of a variety of instrument types: selected-response instruments, including alternate-response, multiple-choice, and matching exercises; created-response instruments, including short-answer questions, completion exercises, numerical problems, and essay questions; laboratory test instruments; and other appropriate instrument types.

The first published package (Physics I) contains multiple-choice instruments. Because of content and difficulty level, they are mainly suitable for use in evaluating students in

Ontario Academic Courses (OAC's).

The second published package (Physics II) contains multiple-choice and alternate-response instruments. Most of these instruments are suitable for use in evaluation at the Senior level. However, some instruments can be used for diagnostic purposes at the Ontario Academic Course level.

The third published package (Physics III) contains a representative sample of created-response instruments: short-answer, completion, essay, and problem instruments. Some selected-response matching exercises are also included. Some of the instruments can be used at the Senior level, some at the Ontario Academic Course level, and some at both levels. Physics III also includes an answer and a scoring scheme for each instrument.

The fourth package (Physics IV), to be published at a later date, contains laboratory test instruments. Some of the laboratory test instruments can be used at the Senior level, some at the Ontario Academic Course level, and some at both levels.

The fifth package (Physics V), to be published at a later date, contains multiple-choice instruments for use at the Ontario Academic Course level.

The ultimate aim of the pool is to put into the hands of physics teachers a resource containing a variety of assessment instruments for the various topics that make up the curriculum. As additional instruments are screened and become available, they will be published in subsequent supplemental packages.

Specifying Content Covered

Each instrument has been coded to the appropriate Ministry of Education curriculum guidelines, S-17A and S.17C, depending on its content. For example, an item on the refraction of light is coded S-17A III.3.a and S.17C II.1.b. The Roman numeral designates the unit, and the number indicates the topic within the unit. When the new Senior Division science guidelines become available, a correspondence table will be provided.

Where appropriate, each instrument has also been coded to the objectives contained in a document prepared by the Science Teachers' Association of Ontario, Senior Division Physics: A Core Curriculum for Grades 11 and 13 (Toronto: STAO, 1977). (The appropriate objectives for the instruments have been included in Appendix A.) For example, an instrument on the topic of refraction of light would be coded 60 and 285 to indicate that it applies to the STAO objective 60, as listed under the core unit "Behaviour of Light and Models of Light", and to objective 285 under the optional unit "Ray or Geometric Optics".

Specifying Behaviour Covered

In the assessment of achievement both content and behaviour objectives should be considered. For the behaviour categories, the system developed by Leopold Klopfer has been used. The complete Klopfer category system attempts to embrace all science education objectives. It includes such behaviour categories as knowledge and comprehension, the processes of scientific inquiry, application, manual skills, attitudes and interests, and orientation. An outline of the Klopfer behaviour categories is included in Appendix B*.

Classifying Instruments Along Two Dimensions

The instruments in this collection are classified along two dimensions:

1. content (keyed to the Ministry of Education guideline(s) and the STAO objectives);
2. behaviour (keyed to the Klopfer categories).

As an example, suppose that a teacher wishes to assess the student's grasp of Snell's law of refraction (S-17A II.3.a, S.17C II.1.b, and STAO objectives 60 and 285). Several of

---

* For further details teachers should consult L. E. Klopfer, "Evaluation of Learning in Science", in Handbook of Formative and Summative Evaluation of Student Learning, ed. B.S. Bloom, J.T. Hastings, and G.F. Madaus, (New York: McGraw-Hill, 1971).

Klopfer's behaviours relating to the law may be tested: knowledge of the law (category A.8); recognition of the law when it is stated in terms quite different from the formal textbook statement (category A.10 or A.11); application of the law in a straightforward numerical problem (F.1); or deduction of the law from a set of laboratory procedures (G.1). The latter may involve all or most of the behaviours listed under category B ("Processes of Scientific Inquiry: Observing and Measuring") and category D ("Processes of Scientific Inquiry: Interpreting Data and Formulating Generalizations") and in some cases could come after the processes described in category C ("Processes of Scientific Inquiry: Seeing a Problem and Seeking Ways to Solve It").

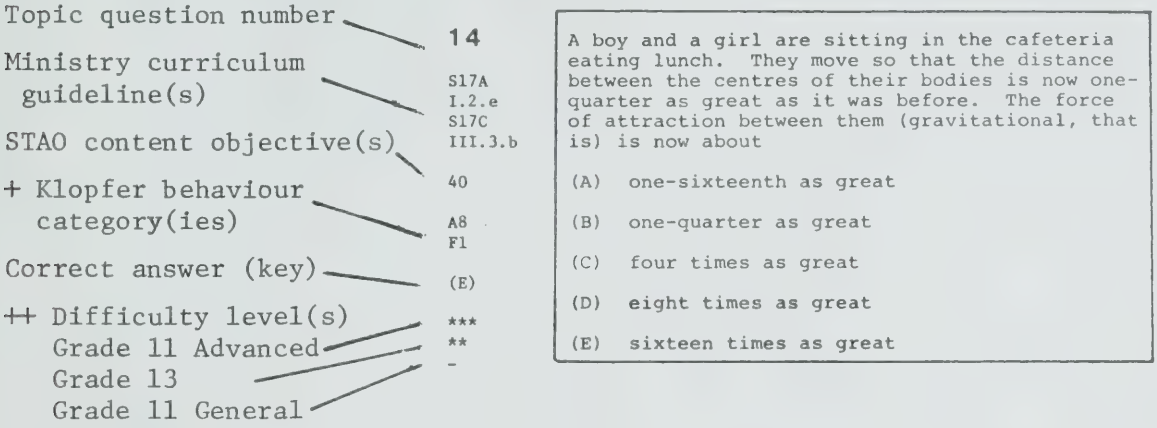
It is important that teachers realize that there was some degree of arbitrariness involved in classifying instruments by STAO content objectives and Klopfer behaviour categories. The behaviour objectives measured by an instrument depend to a considerable extent on the way the particular subject matter was taught. An instrument may be similar to a task already done in class, in which case it may be at the knowledge level, the application level, or even higher. It is felt, however, that the present assignment of objectives to instruments reflects the practice of most teachers in Ontario. It is recognized, however, that different approaches to physics teaching may warrant a change in categorization of an instrument by an individual teacher.

Layout of Instruments

Instruments were typed in a Courier 10 typeface. This typeface facilitates clear copying and easy reading. As a result, the instruments can be photocopied for use in a test or used in the making of transparencies for instruction or review purposes. Sloping symbols were used for physical quantities in order to distinguish them from symbols for units. For example, *m* represents the physical quantity mass, while m represents the unit metre.

Codes specifying content objectives, behaviour categories, keys, and estimated difficulty levels are positioned beside the question in the left margin. This location provides easy reference and also permits the teacher to mask the codes during copying.

The layout of a representative multiple-choice instrument, codes, and code descriptions are shown below.


Topic question number
14
Ministry curriculum guideline(s)
S17A
I.2.e
S17C
III.3.b
STAO content objective(s)
40
+ Klopfer behaviour category(ies)
A8
F1
Correct answer (key)
(E)
++ Difficulty level(s)
Grade 11 Advanced
Grade 13
Grade 11 General
***
**
-
A boy and a girl are sitting in the cafeteria eating lunch. They move so that the distance between the centres of their bodies is now one-quarter as great as it was before. The force of attraction between them (gravitational, that is) is now about
(A) one-sixteenth as great
(B) one-quarter as great
(C) four times as great
(D) eight times as great
(E) sixteen times as great

\+ Where more than one category is given, the main one is given first.
++ See the following section for the meaning of the asterisks.

Specifying the Difficulty Level

The estimated difficulty level for each instrument has been provided. This estimate is based on data derived from screening trials in a number of Ontario classrooms. One asterisk (*) identifies an instrument estimated to be easy (one to which more than 75 percent of the students at the appropriate grade levels are likely to choose or give a correct or acceptable response); two asterisks (**) identify an average or moderate instrument (one that between 50 percent and 75 percent of the students are likely to answer acceptably); and three asterisks (***) identify an instrument classified as difficult (one that fewer than 50 percent of the students are likely to answer acceptably). If a difficulty level is not provided for an instrument for a specific target population, the instrument has not undergone screening trials with this group.

It cannot be too strongly stressed that these ratings are estimates rather than rigid and infallible established standards. The estimated difficulty level is saying, in effect, that on the basis of how students have already performed on a particular instrument, the teacher of the "average" class, using the instrument with the grade for which it was screened, might reasonably expect this level of performance. But if the objective being tested by the instrument has not been the subject of recent instruction, if the student's first language is not English, if the student is especially gifted or has particular difficulties, if the instrument has been screened by only a few students, or if any of a host of other factors come into play, teachers should not be too surprised by a performance that departs from the values provided. It is the responsibility of the teacher to judge each instrument as to its appropriateness for a particular group of students. Difficulty level is only one of many criteria to be used.

Arrangement of Instruments

The instruments are arranged in the same order as the topics in STAO's Senior Division Physics: A Core Curriculum for Grades 11 and 13 (see Appendix A). The topic headings and subheadings, together with their symbols, are outlined at the beginning of this document and in Appendix A. The instruments are then arranged consecutively according to the STAO content objective number. Within each content category, instruments are arranged consecutively according to the Klopfer behaviour categories. As additional instruments for a particular target population and/or of a specific kind become available for a particular topic, teachers may wish to insert them in the appropriate location by STAO content objective number. This process will facilitate for the teacher the selection of instruments that reflect specific objectives. As the technology becomes more sophisticated, the instruments may be stored on magnetic tape and retrieved by these identifiers.

Locating Instruments for a Specific Purpose

The classification of each instrument along two dimensions makes it simple to locate instruments to meet specific needs. Teachers should:

1. decide on the format of the instrument (multiple-choice, short-answer, essay question, or numerical problems, etc.)
2. scan the STAO content objectives (see Appendix A) and select the range of content they wish to test. (Not all instruments can be assigned a specific STAO objective number. The STAO document was not intended to cover all possible physics topics. Where an instrument is outside a STAO content objective, it is designated "S" (supplementary); where the instrument is close to a STAO objective, but only approximately so, it is designated "S", followed by a STAO number. Thus, S 9 describes an instrument whose objective is not quite 9 but is closer to it than to some other objective. Where the instrument does not correspond to a STAO objective, but should follow it in a sequence, it is designated "SS" followed by the STAO number.)
3. scan the Klopfer behaviour categories (see Appendix B) and select the behaviour they wish to test. (Some instruments can be assigned more than one Klopfer behaviour category. Where more than one category is given, the main one is given first.)

Near-Duplicate Instruments

Some instruments are so similar to others that it is not prudent to have them appear in the same test. Near-duplicates have been included and are best for:

1. retesting students after they have been given remedial help;
2. testing the same objective in slightly different ways, where the teacher may prefer one method over the other;
3. testing the same objective on different occasions (e.g. in an end-of-subtopic mini-test and then again in a term test).

Reliability and the Scoring of Instruments

Reliability refers to the reproducibility of a measurement, that is the extent to which teachers can depend on the instrument producing the same results with the same students under the same conditions. Several factors contribute to the reliability of test results: the ability of students to comprehend instructions; the tendency of students to choose one option on a multiple-choice test more frequently than others or to mark an alternate-response instrument true when they are undecided; fatigue; motivation; conditions of testing; adherence to time limits; test wiseness, i.e. the ability of students to identify the correct answer from patterns in the wording or placement of the responses.

The grading or rating of student performance is one of the main factors affecting the reliability of test results. Teachers wishing to improve the reliability of test results should increase scoring accuracy by standardizing test conditions and scoring procedures as much as possible. Teachers should provide students with practice in class with various kinds of instruments before using them on a test. This is particularly important for the more novel kinds of instruments. One way to provide practice is to use transparencies of test instruments during reviews. Students should also be aware of the scoring policy for different kinds of instruments since prior knowledge of the scoring policy affects the emphasis that students place on different components of an answer. The sections that follow describe and give examples of the different kinds of evaluation instruments in the pool and outline the scoring policy used in making the marking schemes for created-response instruments. Example scoring schemes for formal laboratory reports, graphs, and laboratory test instruments are also provided.

Teachers should endeavour to improve reliability. However they should not let the concern for reliability limit the kinds of evaluation instruments used. In selecting or constructing evaluation instruments, the most important question is one of content validity (see page 41).

Selected-Response Instruments

In this type of instrument the student must select the correct answer from a given number of alternatives. Although the student must recall some information, the emphasis is on the process of recognizing or identifying the correct answer. There are three main types of selected-response instruments included in the pool: alternate-response, multiple-choice, and matching exercises.

1. Alternate-Response

An alternate-response instrument provides the student with a statement and requires the student to choose from dual options such as true/false, same/different, better/worse, or yes/no. Because of its length, the alternate-response instrument makes possible a wide sampling of knowledge in a short time. It is useful for measuring the ability to identify statements of facts, definitions of terms, statements of conventions and principles, and to distinguish fact from opinion. It can also be used to measure beliefs and the ability to recognize cause and effect relationships. Alternate-response instruments generally have a lower comprehension level than other kinds of selected-response instruments.

Example

```
S17A
II.2

157

F1
A2

(B)

**
-
**
```

A violinist plays a note whose fundamental frequency is 220 Hz. The third harmonic of that note is 880 Hz.

(A) True

(B) False

2. Multiple-Choice

A multiple-choice instrument consists of an introductory part, called the stem, and several responses. The stem may be in the form of an incomplete statement or a question. The responses may be completions of a statement or answers to a question. One of the responses is the correct answer or key. The student is required to select the correct answer from the responses.

The multiple-choice instrument is one of the most versatile instruments. It can measure achievement at all cognitive levels. However, it is more difficult to create multiple-choice instruments at higher cognitive levels than at lower levels. There are three main kinds of multiple-choice instruments in OAIP: Physics.

a) Traditional multiple-choice instruments. The traditional multiple-choice instrument has four or five responses. Only one response is correct. All the other responses are incorrect. Thus, the traditional multiple-choice instrument is straight forward and easy to read.

Example

S17C
II.6.c

S 84

A1
A8
A3

(B)

-
***
-

Red light of wavelength λ is viewed through a thin soap film held vertically.

At the second dark area from the top, the thickness of the film is

(A) λ

(B) $\frac{3}{4}\lambda$

(C) $\frac{\lambda}{2}$

(D) $\frac{\lambda}{4}$

(E) very much less than λ

b) Multiple-response multiple-choice instruments. A multiple-response multiple-choice instrument provides the student with several statements. One or more of the statements is correct. The student's task is to select the response that contains only the correct statement(s). This kind of multiple-choice instrument nurtures the ability to make fine distinctions. Since multiple-response multiple-choice instruments are generally at a higher comprehension level than traditional multiple-choice instruments, care should be taken in choosing the target student population.

Example

S17C
I.4.f
S 30
A1
A8
(C)
-
***
-

The following information relates to the motion of three objects, P, Q, and R.

I. Object P moves in a straight line with increasing speed.

II. Object Q moves in a circle with constant speed.

III. Object R moves along a curved path with increasing speed.

In which of the three cases has the object an acceleration component in the direction of motion?

(A) I only

(B) I and II only

(C) I and III only

(D) II and III only

(E) III only

c) Assertion-reason multiple-choice instruments. An assertion-reason multiple-choice instrument provides the student with two statements. Each statement may or may not be correct and each statement may or may not be related to the other. The student is required to select from five responses the single response that best describes the two statements and their relation-

ship. Assertion-reason multiple choice instruments nurture high cognitive levels of thought. Because of their format, they too have a relatively high comprehension level.

Example

S17A
IV.2.f
135
397
A2
A1
(C)
***
-
***

This question involves two statements:

I. Uranium has an atomic number of 92.

II. The uranium nucleus contains 92 neutrons.

Which of the following responses correctly describes the two statements?

(A) Both statements are true, and one statement can be used to explain the other.

(B) Both statements are true, but neither statement can be used to explain the other.

(C) Statement I is true.
Statement II is false.

(D) Statement I is false.
Statement II is true.

(E) Statement I is false.
Statement II is false.

3. Matching-Exercise

A matching-exercise instrument consists of two columns with each word, phrase, or sentence in the left column being matched to a number, word, phrase, or sentence in the right column. The statements in the left column are concerned with similar content or processes. To minimize the amount of reading, the longer statement is placed in the left column. To minimize guessing, the right column contains more responses than there are statements in the left column. Also, the student is cautioned that a response in the right column may be used once, more than once, or not at all. A matching exercise permits the surveying of a large body of content in a short time.

Example

S17A
III.3.p
217
216
215
104
B4
F1
A2
**
-
***

Column I lists a number of quantities to be measured. Column II lists a number of instruments available for making measurements.

In the space provided before each quantity to be measured in column I, write the letter corresponding to the instrument from column II that is most suitable for that measurement. A particular instrument from the list may be used once, more than once, or not at all.

	I. Quantity To Be Measured	II. Measuring Instruments and Their Ranges
(A)	__ 1. The potential difference across a flashlight battery.	(A) DC voltmeter (0-10 V)
(F)	__ 2. The current drawn by a 1 Ω resistor connected to a flashlight battery.	(B) DC voltmeter (0-200 V)
(C)	__ 3. The potential difference across the secondary coil of a transformer when the primary is connected to a standard home outlet and has 20 times as many turns as the secondary.	(C) AC voltmeter (0-10 V)
(H)	__ 4. The current drawn by a 60 W light bulb connected to a standard household outlet.	(D) AC voltmeter (0-200 V)
(I)	__ 5. The current induced in a coil of 100 turns by a bar magnet thrust into the coil.	(E) DC ammeter (0-500 mA)
(E)	__ 6. The current drawn by a 100 Ω resistor connected to a flashlight battery.	(F) DC ammeter (0-5 A)
		(G) AC ammeter (0-100 mA)
		(H) AC ammeter (0-5 A)
		(I) Galvanometer (0-10 mA)

Scoring Selected-Response Instruments

The scoring of selected-response instruments is highly reliable. Each part of the answer is either correct or incorrect and is given full marks or none at all. All that is required to score items is a scoring key. Because no subjective judgement is involved, the answer can be rapidly machine-scored with high reliability. Because of the reliability of scoring, these instruments are also referred to as objective instruments.

Created-Response Instruments

In this type of instrument the student must recall a significant portion of the answer. The student must supply a number, word, phrase, equation, or sentence. The student may then be required to write a paragraph or formulate the complete solution to a numerical problem. Created-response instruments permit the student to integrate ideas and express them in writing. There is freedom to organize the information and express a depth of knowledge. The uniqueness of these instruments lies in their potential to evaluate the ability to supply data rather than merely recognize, interpret, and apply data.

There are four main types of created-response instruments in the pool: short answer, completion, essay, and numerical problem.

1. Short-Answer

In the short-answer instrument a question is asked and the student responds with a word, phrase, number, symbol, or formula.

Example

Note: Do not permit the use of calculators for this series of diagnostic problems. The objective is to test understanding of the laws of exponents. These are pure numbers, not measured quantities. Any mathematically correct answer is acceptable.

S17A I.1.a S17C I.1.d

S 1 A7 F1 A4

For items 1-9, simplify the expression and place your answer, using power of ten notation, in the space provided.

			Answer
*	√ √	(1) $10^5 + 10^6$ = _____	(1.1×10^6)
*	√ √	(2) $10^5 - 10^4$ = _____	(9×10^4)
**	√ √	(3) $10^3 - 10^4$ = _____	(-9×10^3)
	√ √	(4) $5.0 \times 10^5 + 4.0 \times 10^5$ = _____	(9.0×10^5)
	√ √	(5) $7.0 \times 10^4 - 3.2 \times 10^4$ = _____	(3.8×10^4)
	√ √	(6) $2.0 \times 10^6 + 3.0 \times 10^5$ = _____	(2.3×10^6)
	√ √	(7) $2.0 \times 10^5 + 3.0 \times 10^6$ = _____	(3.2×10^6)
	√ √	(8) $5.1 \times 10^6 - 1.0 \times 10^5$ = _____	(5.0×10^6)
	√ √	(9) $4.0 \times 10^5 - 7.5 \times 10^6$ = _____	(-7.1×10^6)

2. Completion

In the completion instrument an incomplete statement is made. The student completes the statement with a word, phrase, number, symbol, or formula. It is essential that a sufficient number of key words be retained in the completion statement to delineate the task and that the blanks be placed fairly late in the statement.

Example

S17A II.1.b S17C II.3.a

69

A2

*
*
*

A wave in which the particles of the medium vibrate at right angles to the direction of wave travel is called a _____ wave.

3. Essay

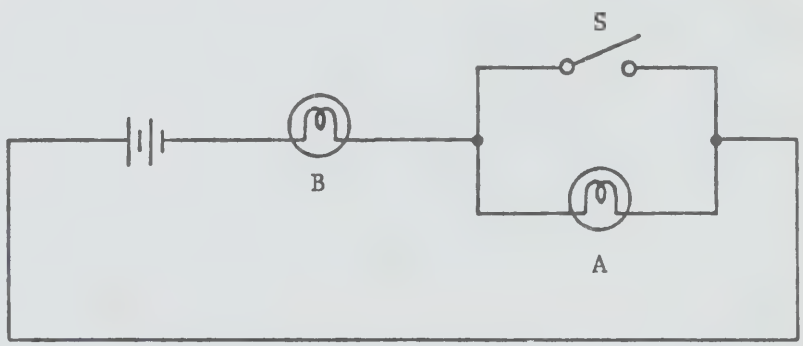
An essay instrument requires the student to answer a more general question. This permits the student to integrate ideas and express them in writing. The student is given some freedom to organize the information and exhibit a depth of knowledge. Essay instruments are of two types; they vary with reference to how much structure is placed on the content and form of the response and how much time is involved in answering.

a) Restricted-response essay instruments. In restricted-response essay instruments a limit is placed on both the content and form of the response. These factors improve the scoring accuracy and reliability of the instrument. Also, the restricted-response essay instrument does not require a long time to answer and permits the surveying of a realistic amount of content.

Example

S17A
III.2.g
104
105
F3
A3
**
-
***

Two identical light bulbs, A and B, are connected as shown in the following diagram.



(a) (i) If the switch, S, is closed, what change, if any, will occur in the intensity with which A glows?

(ii) Explain your answer.

(b) (i) If the switch, S, is closed, what change, if any, will occur in the intensity with which B glows?

(ii) Explain your answer.

b) Extended-response essay instruments. The extended-response essay instrument stresses depth and scope of knowledge, with the emphasis on freedom of expression and the encouragement of analytical and critical thinking and originality. Such instruments measure students' global attack on a problem. However, because of the length of the answer required and the amount of time involved, extended-response instruments do not permit the surveying of a large amount of content.

With the emphasis on language across the curriculum, this type of instrument should be an integral part of the evaluation procedures used by the teacher. A detailed scoring scheme is required to improve the reliability of scoring.

Example

S17C
III.3.a
449
A9
E5
I3
-
**
-

Write a two-page critical evaluation of the Copernician theory of the solar system. Begin by stating the postulates of the theory. Then evaluate and discuss each of the postulates. Include scientific observations that support your statements.

4. Numerical Problem

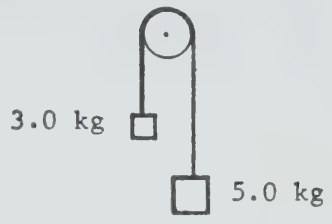
In a numerical-problem instrument the student is given numerical data for several variables and is required to find a numerical answer to the question. The solution requires a summary of the information, identification of the problem, an analysis of the data for the purpose of identifying assumptions, laws, and relationships that may apply, and finally the synthesis of a solution. The

solution involves behaviours in Klopfer's behaviour category F and the application of scientific knowledge and methods.

Example

S17C
III.6.c
56
A8
F1
-
***
-

A light cord passes over a light, frictionless pulley as shown. A 5.0 kg mass hangs from one end of the cord and a 3.0 kg mass hangs from the other end. The system is initially at rest.



Determine the speed of each mass when the 5.0 kg mass has fallen 0.80 m by using the principle of conservation of energy. (g = 10 N/kg)

Note: Other methods of determining the speed will not be accepted.

Scoring Created-Response Instruments

The scoring of created-response instruments involves a number of subjective judgements on the part of the scorer. These subjective judgements are minimized and the scoring is more reliable if a detailed scoring scheme is followed. A scoring scheme has been provided for each created-response instrument in OAIP: Physics.

The scoring policy adopted for OAIP: Physics is that of "a point for a point". One scoring point is awarded for each clearly identifiable step or element that makes an essential contribution to a correct and complete answer. An element is scored as either ✓ or 0; that is, an element is either there or it isn't and is credited accordingly. There is no penalty for omitting intermediate steps, provided the logic is sound.

The details of the scoring policy adopted for created-response instruments is summarized below. A ✓ indicates that a scoring point is awarded for the element indicated. The teacher should use discretion in the use of the scoring policy.

Scoring Policy Adopted For Created-Response Instruments

Setting Up The Problem

✓ extraction of relevant data (including units and assignment of data to the correct variable)
✓ statement of convention (e.g., take downward as positive)
✓ listing of implied or assumed values (e.g., $v_i = 0$, $a = g$)
✓ statement of relevant general principle or law
✓ drawing of a sketch showing the situation and the objects (e.g., projectile thrown from building)

Equations

✓ choice of relevant equation (e.g., $F = ma$)
✓ correct substitution of data into the equation

Mathematical Computation

✓ rearranging the variables in an equation in order to isolate the unknown (either before or after substitution)
✓ performing key steps needed in order to obtain the final answer, such as obtaining the value of a constant from tables or a calculator, simplification, factoring, or applying a mathematical identity

Final Answer

✓ magnitude (numeral and exponent)
✓ unit
✓ direction (when applicable)
✓ sign (when appropriate) (e.g., gain or loss of energy)
✓ number of significant figures (when appropriate)
✓ final statement (answer to the question)

Special Considerations

i) Free-Body Diagrams

✓ each correctly labelled vector

ii) Vector Sketches

for each correct vector -
✓ label, e.g., v(a/g) (air relative to ground)
✓ magnitude (where appropriate) e.g., 400 m/s
✓ direction (where appropriate) e.g., [N]
✓ orientation with reference to other vectors, e.g. head to head, tail to tail

iii) Vector Scale Diagrams

✓ indication of scale
✓ appropriateness of scale
✓ constructed length of each given vector
✓ constructed direction of each given vector
✓ length of each measured vector
✓ determination of the true length of each measured vector (using scale)
✓ direction of each measured vector

iv) Sketched Graphs

✓ correct shape
✓ correct placement with reference to origin
✓ correct slope at key locations (e.g., origin)

v) Plotted Graphs

✓✓ appropriateness of title
✓✓ assignment of variables to axes
✓✓ labelling quantities on axes
✓✓ labelling units on axes
✓✓✓✓ appropriateness of axes scales
✓✓✓✓ accuracy of plotted points
✓✓ appropriateness of indication of plotted points (error bars)
✓✓✓✓ appropriateness of line of best fit
✓✓✓ neatness

Note: 1. See "Scoring Scheme for Graphs" on page 40.
2. Allocate the tick marks ✓ indicated, sum, and divide by five to achieve a realistic weighting.

vi) Ray Diagrams

✓ each appropriate ray
✓ each correct arrowhead
✓ each appropriate angle
✓ each characteristic of the image

Guidelines for Implementing the Scoring Policy

a) Students should be encouraged to substitute units with numerals into equations and to carry units throughout the solution of a problem. Physical quantities, such as mass, force, and momentum, are completely described only when units are included with numerals. The substitution of units has several merits: it provides a check on the accuracy of the equation; it points out the need for consistent units; and it identifies the unit of the answer. Students should not be penalized if units are dropped part way through the solution of a problem. Some units are cumbersome to carry. But if units are dropped, students should write "units dropped" as a signal to the scorer of a conscious decision to do so.

b) Mathematical computations should not take precedence over the physics in a question. Accordingly, a minimum

number of points have been allotted for arithmetical manipulation. For this reason, the use of calculators in created-response instruments is optional.

c) A mechanical error should result in the loss of marks only for the step in which the error occurred. The scorer should trace the solution through to the final answer without deducting further marks, unless additional errors are made.

d) Students should be encouraged to show their complete solution to a problem. However, full marks are assigned to the correct answer even if intermediate steps are omitted, provided the logic is sound.

e) The final answer to all created-response instruments should be in the form of a statement. This statement is an answer to the question asked in the problem.

Example Created-Response Instruments and Scoring Schemes

Two example created-response instruments, codes, answers, and scoring schemes are shown below.

a)

S17A
III.2.g
104
F1
A8
A2
*
-
**

The resistance from head to toe of a typical human body with wet skin is 1000 Ω.

What current would flow through a body connected to a 12.0 V DC battery?

Scoring Scheme	Answer	
✓	R = 1000 Ω	V = 12.0 V DC
✓	$I = V/R$	
✓	= 12.0 V/1000 Ω	
	= 0.0120 A	
✓ ✓	= 1.20×10^{-2} A	
✓	A current of 1.20×10^{-2} A would flow through the body.	

b)

S17C
I.4.d

24

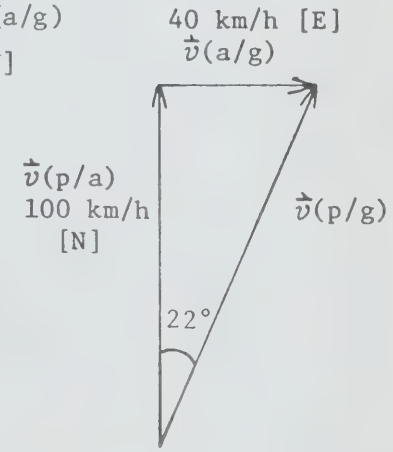
F1
A7
A8

***
**
-

A plane has an airspeed of 100 km/h. The pilot points the plane directly north. A wind is blowing from the west at 40 km/h.

Using a vector diagram, find the velocity of the plane relative to the ground.

Scoring Scheme	Answer	
	Let $\vec{v}$(p/g) represent the velocity of the plane relative to the ground.	
	$\vec{v}$(p/a) represent the velocity of the plane relative to the air	
	$\vec{v}$(a/g) represent the velocity of the air relative to the ground.	
√	Then $\vec{v}$(p/g) = $\vec{v}$(p/a) + $\vec{v}$(a/g)	
	$\vec{v}$(p/a) = 100 km/h [N]	
√	$\vec{v}$(a/g) = 40 km/h [E]	
	$\vec{v}$(p/g) = ?	



Vector $\vec{v}$(p/a)

√	$\vec{v}$(p/a) labelled	
√	magnitude labelled	100 km/h
√	direction labelled	[N]

Vector $\vec{v}$(a/g)

√	$\vec{v}$(a/g) labelled	
√	magnitude labelled	40 km/h
√	direction labelled	[E]

Scoring Scheme	Answer	
	Vector v(p/g)	
✓	$\vec{v}$(p/g) labelled	
	Orientation of Vectors	
✓ ✓	orientation of v(a/g) and v(p/a) to each other	
✓	orientation of v(p/g) to the other two vectors	
	Solution: Scale Diagram	
✓	indication of scale	Scale: 1 cm represents 20 km/h
✓	appropriateness of scale	
✓	constructed length of v(p/a)	5 cm
✓	constructed direction of v(p/a)	[N]
✓	constructed length of v(a/g)	2 cm
✓	constructed direction of v(a/g)	[E]
✓	measured length of v(p/g)	5.4 cm
✓	determination of v(p/g)	5.4 x 20 km/h
✓		= 1.1 x 10^2 km/h
✓	measured direction of v(p/g)	[N 22° E]
✓ ✓	statement	The velocity of the plane with respect to the ground is 1.1 x 10^2 km/h [N 22° E].

Laboratory Test Instruments

1. Laboratory Exercises

Courses in physics at the secondary school level must be laboratory based and will therefore involve significant numbers of laboratory exercises (experiments) performed by students. In addition to contributing to knowledge categories, the performance of these exercises will contribute to the development of student behaviours, which Klopfer lists as follows:

- Processes of Scientific Inquiry (categories B,C,D)
- Manual Skills (category G)

Many teachers pair up students for laboratory experiments. One approach is to make one student responsible for doing the experiment and the other for completing the write-up. The write-up is handed in at the end of the period. The recorder uses carbon paper to make three copies: one for each student and one for the teacher. The duties of the recorder and experimenter are reversed for every other experiment.

In order for students to achieve speed and accuracy in writing laboratory reports, they must obtain practice at other times than during laboratory tests. It is suggested that each student prepare formal reports regularly during the year.

It is essential that the teacher provide feedback on the laboratory reports. Because the teacher has limited time available for marking, a common format for the report and the use of a scoring scheme similar to the one shown below for grading the laboratory report and for providing feedback are suggested.

2. Scoring Scheme for Formal Lab Reports

Laboratory Title _____

Candidate's Name _____

Attribute	Scale
1. Title	0 1 2
2. Problem: question under investigation	0 1 2
3. Hypothesis: prediction about the question	NA 0 1 2
4. Materials: a list and/or diagram	0 1
5. Procedure: a list of the key steps	0 1 2 3
6. Observations: descriptive paragraph; table of values, including units	0 1 2 3 4 5
7. Graph: see "Scoring Scheme for Graphs"	NA 0 1 2 3 4 5
8. Calculations: samples, including units analysis	0 1 2 3 4 5
9. Discussion: validity of results, sources of error	0 1 2 3 4 5
10. Conclusion: answer to the question, comment on validity of the hypothesis	0 1 2 3 4 5

_____/

Comments: _____

Supervision by the teacher of the students' activities during the performance of these exercises, and the marking of the students' laboratory reports, may be sufficient for the teacher to determine whether the desired behaviours have been acquired. However, in addition, it may be helpful occasionally for the teacher to administer a laboratory test. OAIP: Physics includes two kinds of laboratory test instruments: laboratory-skill test instruments and laboratory-experiment test instruments. A description and examples of each kind follow.

3. Laboratory-Skill Test Instruments

Laboratory-skill test instruments enable the teacher to evaluate students' skill in using common laboratory equipment. The Subject Advisory Group believes that the skill instruments should be used only after students have been taught the skills and have practised them. The format for arranging the instruments is referred to as a bell-ringer test. A number of different test stations are arranged around the room. Question cards and equipment are placed at each station. The student reads the question and makes a straightforward measurement, using the equipment. At suitable intervals (say, every five minutes) the teacher uses a bell to signal students to move on to the next station, hence the name bell ringer.

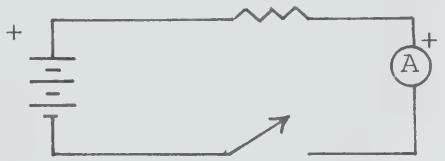
In the bell-ringer tests students are observed using various instruments and a mark is assigned on the basis of their ability to use the instrument correctly to a degree of accuracy determined by the teacher. In order to have a standard of accuracy for comparison, the teacher can use the class histogram and either the mean or mode of the results, depending on the shape of the distribution. Alternately, the teacher can use the instruments to determine a value and can compare the students' results to this value. An example instrument suitable for use at one station is shown below. Each laboratory-skill test

instrument in the pool contains a statement of the question, a list of materials to be placed at the station, and notes to the teacher.

4. Example Laboratory-Skill Test Instrument

Note to the Teacher

1. Prewire the circuit as shown below.



2. Use a source whose electric potential stays constant.
3. Use a resistor that doesn't change resistance for the electrical potential used.

S17A
III.2.c
2
4
101
A7
B3
*
-
*

MEASUREMENT - ELECTRIC CURRENT

Problem

Determine the current that flows through the circuit when the switch is closed. Include the uncertainty of your measurement.

Materials

ammeter	constant voltage source
resistor	connecting wires
switch (SPST)	

5. Laboratory-Experiment Test Instrument

A laboratory-experiment test instrument presents a problem and requires the student to design and implement a procedure to solve the problem and to report the results. The Subject Advisory Group feels laboratory-experiment test instruments may be used either before or after the topic has been taught. The test may present an entirely new situation and challenge the student to design a procedure to solve a problem. In this case the laboratory-experiment test instrument is being used as a teaching tool. At the other extreme, the test may be a repetition

of a laboratory exercise that has already been performed. Ideally, however, the test instrument presents a slightly new situation in the sense that it requires a modest extension, or modification, of work already done.

To standardize the scoring procedure, OAIP: Physics uses the same format for all laboratory-experiment test instruments. Also, the form of the answer has been standardized through the provision of a common answer sheet.

Each laboratory-experiment test instrument consists of a note to the teacher, an introduction, a statement of the problem, a list of materials, and an outline of the sequence to be followed in solving the problem and writing up the report. The test is broken into two phases.

In "Part A - Experiment Design", the students have a specified amount of time to state the problem, examine the materials, draw a diagram, and list the main steps of the method proposed for solving the problem. At the teacher's discretion the materials may contain "red herrings" to distract the students. The form of the student's answer is standardized by means of a common answer sheet, titled "Part A - Experiment Design". Space is provided for answers under the headings: "Problem", "Materials", "Diagram", and "Method". The student submits the answer sheet to the examiner before starting Part B.

At the beginning of "Part B - Experiment Report", the examiner provides the student with the procedure to be followed. Alternately, the examiner may choose to let the student use his/her own procedure, if it is judged to be complete and safe. The student is also given an answer sheet titled "Part B - Experiment Report". A specified amount of time is allowed for performing the procedure and reporting the results. The report is organized under the headings: "Observations", "Calculations", "Accuracy", and "Conclusion".

6. Example Laboratory-Experiment Test Instrument

An example of a laboratory-experiment test instrument and the two answer sheets are shown below.

Note to the Teacher

1. The experiment can be done on an individual basis.
2. Caution students against stray reflections and the danger of looking directly into the laser beam.
3. Ensure that the laser beam does not cross a traffic area or reflect off a shiny object.
4. Provide the students with the wavelength of the laser light in nanometres.
5. The red herring for this experiment can be a micrometer screw gauge.

S17C
III.6.a
86
D1
C4
C3
B4
-
**
-

DOUBLE SLIT SEPARATION USING A LASER

Introduction

This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing up a report. You have 40 min to complete the test. The test consists of two parts.

In "Part A - Experiment Design" you have 15 min to state the problem, examine the materials, and list in order the main steps of a method for solving the problem.

In "Part B - Experiment Report" you have 25 min to implement the procedure supplied by the examiner and to write up a report.

Problem

Sometimes physicists use an indirect method to determine the size of an object or quantity. Your problem is to design and implement a method to indirectly determine the separation between two slits.

Materials

The solution of the problem may require some or all of the following materials:

laser of known wavelength	metre stick
double slit of unknown separation	screen
holder for the double slit	masking tape
metric tape measure	

CAUTION: LIGHT FROM A LASER IS HARMFUL TO THE EYE. DO NOT LOOK DIRECTLY INTO THE LASER BEAM AND GUARD AGAINST STRAY REFLECTIONS.

Part A - Experiment Design (15 min)

The examiner will provide you with an answer sheet titled "Part A - Experiment Design." Record your work for Part A on this sheet.

a) Under the heading "Problem" write in your own words a clear statement of the problem under investigation.

b) Examine the materials supplied by your examiner. Under the heading "Materials" list the materials you will need to solve the problem.

c) Under the heading "Diagram" draw a simple diagram showing the proposed experiment set up.

d) Under the heading "Method" list in order the steps of the method you will use to solve the problem.

e) At the end of the prescribed time submit "Part A - Experiment Design" to the examiner and continue with Part B.

Part B - Experiment Report (25 min)

The examiner will provide you with a sheet titled "Procedure", or you may be permitted to use your own procedure from Part A. You will also be provided with an answer sheet titled "Part B - Experiment Report". Record your work for Part B on the answer sheet under the appropriate headings.

a) Perform the experiment by following the steps outlined in the procedure.

b) Under the heading "Observations" record the results of the experiment. Use statements, descriptive paragraphs, tables of data, and graphs where appropriate.

c) Under the heading "Calculations" show sample calculations. Include relevant equation(s) and use units analysis throughout the calculations.

d) Under the heading "Accuracy" identify sources of error and discuss the accuracy of each measurement.

e) Under the heading "Conclusion" outline an answer to the problem and comment on the validity (quality or soundness) of the final answer.

f) At the end of the prescribed time submit "Part B - Experiment Report" to your examiner.

PROCEDURE SHEET

Double-Slit Separation Using A Laser

Note: This sheet must be returned to the examiner at the end of this test.

Method

a) Do not turn on the laser until you are ready to take measurements.

b) Position the screen at least 3 m from the laser.

c) Mount the double slit close to and directly in front of the laser.

d) Turn on the laser.

CAUTION: DO NOT LOOK DIRECTLY INTO THE LASER BEAM AND GUARD AGAINST STRAY REFLECTIONS.

e) Adjust the position of the slits to obtain a double-slit interference pattern on the screen.

f) Measure on the screen the distance between a known number of maxima. Note the number of dark fringes enclosed by these maxima.

g) Calculate and record the separation between the centres of adjacent maxima.

h) Measure and record the distance from the double slit to the interference pattern on the screen.

i) Obtain and record the wavelength of the light from the laser.

j) Use the relationship between the variables to calculate the slit separation. Show all calculations.

k) When you have finished, submit this procedure sheet and the answer sheet "Part B - Experiment Report" to the examiner.

ANSWER SHEET

Lab Test Instrument: _____

Candidate's Name: _____

Part A - Experiment Design

Organize the experiment design under the following headings: Problem, Materials, Diagram, Method. Use the front and back of this sheet if necessary.

ANSWER SHEET

Lab Test Instrument: _____

Candidate's Name: _____

Part B - Experiment Report

Organize the experiment report under the following headings: Observations, Calculations, Accuracy, Conclusions. Use the front and back of this sheet if necessary.

Note: To save space in this document the answer sheets have been placed on one page. When they are used with students, sufficient space must be left for a complete answer. Master sheets have been provided in the laboratory-test-instrument package.

7. Administering Laboratory Test Instruments

Laboratory tests should foster creativity or at least activity on the part of each student, rather than the passivity that is sometimes possible when a student is a member of a group of two or more. Most of the laboratory test instruments can be used by individuals working alone. (There are a few exceptions.) However, this arrangement presents a logistical problem. How does a teacher arrange for each member of the class to perform a test? And what steps can the teacher take to minimize the passing of procedural ideas (orally or visually) from student to student? We think that there are several possibilities.

a) The teacher may require the students to do "Part A - Experiment Design" for the test as a paper-and-pencil exercise a day or more before the date of the test. This should ensure more effective use of time during the test period.

b) Since a teacher is not likely to have available thirty sets of apparatus for one particular test, and if several short tests are available, several different stations may be set up in the laboratory. Students rotate to the different stations in turn. However, even with this arrangement, it will probably be impossible to have each member of the class busy at a test at any given time. The section that follows addresses this problem.

c) Activity must be provided for those students not actively engaged in performing the test. Here creativity on the part of the teacher is necessary - creativity that we find difficult to outline because so much depends on the size of the classroom and the layout of the facilities in the room. The following are methods that have been used successfully:

(i) The class may be set to work on an assignment such as the working of numerical problems, the completion of laboratory reports, library research, finalizing of notes, summarizing or reviewing the unit, etc. A limited number of students may then be withdrawn at intervals to perform the laboratory test.

(ii) An obvious variation of (i) above, but one worthy of separate listing, is that half of the class may be writing the normal test for the unit while the other half performs the laboratory test.

(iii) A variation of (ii) might be that one item on the unit test is practical, and each student is given a time during the test period to carry out this laboratory part. Four or five identical stations may be set up for this purpose.

(iv) An extension of the procedure in (ii) is possible if the testing is done over two days. One-half of the class does the written portion and one-half does the laboratory portion on each of the two days.

The number of possibilities seems large. Admittedly, none of them eliminates all of the potential problems, but the advantages of laboratory tests are sufficiently great to warrant their use.

8. Scoring Laboratory Test Instruments

Many elegant methods may be devised to evaluate student performance during laboratory tests. We realize, however, that teachers have very limited time available for this purpose. The method of evaluation should, therefore, be reasonably simple. The simplest procedure would be to administer a quantitative test and devise a marking scheme

based solely on the accuracy of the result. For example, suppose that the problem is as follows:

> Imagine that you are working as a technologist. Your problem is to design and implement a method to determine the density of a liquid and to identify the liquid by its density.

The teacher has determined in advance that the density is 850 kg/m^3. The mark assigned can then be determined solely by how closely the student's result corresponds to this value and whether or not the student can identify the liquid. However, this places undue emphasis on the result and ignores the processes and motor skills.

Other methods may involve one or more of the following steps:

a) The student is asked to submit a preliminary proposal which is then evaluated.

b) The student is asked to submit a report, complete with diagram(s), which is then evaluated.

c) The student is asked to write an abstract of the exercise. This would be a brief, informal summary in which the student states the purpose of the exercise, the principle(s) on which the procedure was based, and the results obtained. An example follows.

Example Abstract

The density of a rectangular block of metal was determined by two methods, which differed only in the technique used to find the volume of the block. In the first method the volume was found by the displacement of water. In the second method the dimensions of the block were measured, and the volume was calculated. The first method gave a value of 41.6 cm^3. The second gave a value of 41.5 cm^3.

The second method produced more accurate results because there was an error of 5 percent in reading the ruler and 7 percent in collecting the overflow and reading the graduated cylinder.

d) Each student's actions are observed and his/her laboratory techniques and psychomotor skills are evaluated.

The Subject Advisory Group has attempted to combine the positive features of all the methods described above without making the scoring time unrealistic. The scoring policy for OAIP: Physics laboratory test instruments has been standardized through the use of a common scoring scheme for all instruments. The scoring scheme combines the characteristics of a checklist and a rating scale.

A checklist is a measuring device used to record whether an element is present or absent. The element is scored either full marks or zero. The checklist is quantified by counting up the marks.

A rating scale is used to evaluate attributes that can be measured in terms of degrees. It consists of a set of attributes to be judged and a scale indicating the degree to which each attribute is present. It provides a common framework for comparing all students on the same set of characteristics and provides a convenient method of recording the judgement and comments of observers. A numerical rating scale includes a set of numbers beside each attribute. The rater circles the number that indicates the degree to which each attribute is present. The final grade is obtained by summing the circled numbers.

A scoring scheme for laboratory test instruments and a scoring scheme for graphs are shown on the following pages. When a graph is part of the test, the total of the graph score is divided by five before the score is entered in the laboratory test instrument scale. If no graph is involved, the scorer circles NA on the scoring scheme for laboratory test instruments and decreases the total accordingly.

a) Scoring Scheme For Laboratory Test Instruments

Laboratory Test Instrument: _____

Candidate's Name: _____

Attribute	Scale
Part A - Experiment Design	
1. Statement of the problem.	0 1
2. Selection of appropriate materials.	NA 0 1
3. Diagram showing experiment set-up.	NA 0 1 2 3
4. Steps of the method.	0 1 2 3 4 5
Part B - Experiment Report	
5. Skill in using common laboratory materials and instruments.	0 1 2 3
6. Performance of common laboratory techniques with care and safety.	0 1 2
7. Organization and completeness of the observations.	0 1 2 3 4 5
8. Graph. (See scoring scheme for graphs divided by five.)	NA 0 1 2 3 4 5
9. Calculations: knowledge of relationships and use of units analysis.	NA 0 1 2 3 4 5
10. Discussion of sources of error and the accuracy of measurements.	0 1 2 3 4 5
11. Conclusion and discussion of the validity of the answer.	0 1 2 3 4 5
Total	/

Comments: _____

_____

_____

b) Scoring Scheme For Graphs

Laboratory Test Instrument: _____

Candidate's Name: _____

Attribute	Scale
1. The graph has an appropriate title.	0 1 2
2. The dependent (or appropriate) variable is plotted on the vertical axis.	0 2
3. The quantities are labelled correctly on the axes.	0 1 2
4. The correct units are shown on the axes.	0 1 2
5. The scale of the graph is appropriate.	0 1 2 3 4
6. The points are plotted accurately.	0 1 2 3 4
7. The error for the points is appropriately shown.	0 1 2
8. The curve is appropriate for the trend.	0 1 2 3 4
9. The graph is neat.	0 1 2 3
	/25

Comments: _____

_____

Matching Evaluation Instruments to Objectives

In the selection or construction of an instrument for a classroom test, a key consideration is "Does the evaluation instrument measure an objective that the teacher has for the topic?". Consider four objectives for the topic of electrical resistance.

The student should be able to:

1. write a definition in his/her own words for the ohm;
2. identify from a set of factors four factors that affect the resistance of a conductor;

3. given the resistance of each resistor connected in parallel, calculate the total effective resistance of the combination;
4. given a power supply, resistor, connecting leads, switch, voltmeter, and ammeter, design and do an experiment to determine the resistance of the resistor.

Each objective requires the use of a different evaluation instrument: objective (1), a restricted-response essay instrument; objective (2), a multiple-choice instrument; objective (3), a numerical-problem instrument; objective (4), a laboratory-experiment test instrument. An observation instrument should be used with the laboratory test instrument in order to improve the scoring of lab techniques, skills, and the final answer.

These examples illustrate the variety of evaluation instruments teachers need to evaluate the numerous objectives of classroom instruction. Each kind of instrument is suitable for a range of objectives, but one instrument is more appropriate than another for a particular objective (e.g., rating scales for evaluating attitudes and interests, numerical problems for evaluating the application of knowledge and mathematics).

The most important consideration for the teacher in choosing or constructing an evaluation instrument is one of content validity. To what extent will the results of the instrument serve the particular purpose for which it was intended? The content validity of an instrument is high if it measures the objectives of classroom instruction.

The table that follows summarizes the Klopfer behaviour categories and the kind of evaluation instruments in the pool. It shows the range of objectives for which each instrument is most appropriate.

MATCHING EVALUATION INSTRUMENTS TO BEHAVIOURS

Instruments

Behaviours

Rating Scale	Checklist	Lab Experiment	Lab Skill	Numerical Problem	Extended-Response Essay	Restricted-Response Essay	Completion	Short Answer	Matching Exercise	Multiple Choice	Alternate Response		
Observation Instruments		Lab Test Instruments		Created-Response Instruments					Selected Response Instruments				
		x	x	x		x	x	x	x	x	x	A.1	Knowledge of Specific Facts
		x	x	x		x	x	x	x	x	x	A.2	Knowledge of Scientific Terminology
		x	x	x		x	x	x	x	x	x	A.3	Knowledge of Concepts of Science
		x	x	x		x	x	x	x	x	x	A.4	Knowledge of Conventions
		x		x		x	x	x	x	x	x	A.5	Knowledge of Trends and Sequences
		x		x		x	x	x	x	x	x	A.6	Knowledge of Classifications, Categories, and Criteria
		x	x	x		x	x	x		x	x	A.7	Knowledge of Scientific Techniques and Procedures
		x		x		x	x	x		x	x	A.8	Knowledge of Scientific Principles and Laws
		x		x		x	x	x		x	x	A.9	Knowledge of Theories or Major Conceptual Schemes
		x		x		x	x	x		x	x	A.10	Identification of Knowledge in a New Context
		x		x		x	x	x		x	x	A.11	Translation of Knowledge from One Symbolic Form to Another
x	x	x	x									B.1	Observations of Objects and Phenomena
x		x	x									B.2	Description of Observations, Using Appropriate Language
x		x	x									B.3	Measurement of Objects and Changes
	x	x	x		x	x						B.4	Selection of Appropriate Measuring Instruments
x		x	x		x	x				x		B.5	Estimation of Measurements and Recognition of Limits in Accuracy
	x	x		x		x	x	x		x	x	C.1	Recognition of a Problem
		x			x	x						C.2	Formulation of a Working Hypothesis
		x								x		C.3	Selection of Suitable Tests of a Hypothesis
		x			x	x						C.4	Design of Appropriate Procedures for Performing Experiments
		x		x	x	x				x		D.1	Processing of Experimental Data
		x		x	x	x						D.2	Presentation of Data in the Form of Functional Relationships
		x		x	x	x				x		D.3	Interpretation of Experimental Data and Observations
		x		x	x	x				x		D.4	Extrapolation and Interpolation
		x		x	x	x				x		D.5	Evaluation of a Hypothesis Under Test in the Light of Data Obtained
		x		x	x	x						D.6	Formulation of Generalizations Warranted by Relationships Found
										x		E.1	Recognition of the Need for a Theoretical Model
					x	x						E.2	Formulation of a Theoretical Model to Accommodate Knowledge
					x	x						E.3	Specification of Relationships Satisfied by a Model
					x	x						E.4	Deduction of New Hypotheses from a Theoretical Model
					x	x				x		E.5	Interpretation and Evaluation of Tests of a Model
					x	x						E.6	Formulation of a Revised, Refined, or Extended Model
				x	x	x				x		F.1	Application to New Problems in the Same Field of Science
				x	x	x				x		F.2	Application to New Problems in a Different Field of Science
				x	x	x				x		F.3	Application to Problems Outside of Science (Including Technology)
x	x	x	x									G.1	Development of Skills in Using Common Laboratory Equipment
x	x	x	x									G.2	Performance of Common Laboratory Techniques With Care and Safety
x	x											H.1	Manifestation of Favourable Attitudes Towards Science and Scientists
x	x											H.2	Acceptance of Scientific Inquiry as a Way of Thought
x	x											H.3	Adoption of Scientific Attitudes
x	x											H.4	Enjoyment of Science Experiences
x	x											H.5	Development of Interests in Science and Science-Related Activities
x	x											H.6	Development of Interest in Pursuing a Career in Science
				x	x	x	x	x	x	x	x	I.1	Knowledge of Relationships Among Various Types of Statements in Science
					x	x				x	x	I.2	Recognition of the Philosophical Limitations and Influence of Scientific Inquiry
					x	x	x	x	x	x	x	I.3	Historical Perspective: Recognition of the Background of Science
					x	x				x	x	I.4	Realization of the Relationships Among Science, Technology, and Economics
					x	x				x	x	I.5	Awareness of the Social and Moral Implications of Scientific Inquiry and the Results

A. Knowledge And Comprehension

B.0 Observing And Measuring

C. Seeing a Problem And Seeing Ways To Solve It

D. Interpreting Data And Formulating Generalizations

E. Building, Testing, And Revising Theoretical Models

F. Application of Knowledge And Math

G.0 Manipulative Skills

H.0 Attitudes And Interests

I.0 Orientation

Conventions

The conventions adopted are the usual ones found in secondary school physics. Approximate values of physical constants are used unless it is otherwise stated (e.g., 10 m/s^2 [down] for acceleration due to the earth's gravitational field; and 3×10^8 m/s for the velocity of light in vacuo or in air). All graph axes are assumed to have linear scales unless non-linear scales are indicated in a particular case. Students must be told which conventions apply when the instruments are used in class-evaluation situations.

Suggested Uses for the Instruments

The instruments in this pool may be used in the following or similar situations:

- final examinations
- term tests
- topic or subtopic tests
- weekly tests
- spot tests
- reviews (Make a transparency and teach using the instrument.)
- diagnostic tests (See notes below.)
- feedback tests to judge the effectiveness of remedial work for students having difficulty with some aspect of physics
- laboratory tests

Diagnostic Tests

Physics is a hierarchical discipline. A grasp of basic terms and concepts is essential to an understanding of its laws and principles and ultimately its theories. As a result, students with a poor foundation or a "knowledge gap" experience more and more difficulty as the course progresses. The early identification of knowledge gaps is of great benefit to both student and teacher.

Diagnostic instruments are useful for identifying knowledge gaps. They measure achievement in a narrow content area. Diagnostic instruments usually test one concept or the

mastery of a one-step task. These instruments pinpoint specific strengths and weaknesses as a basis for remedial measures.

Diagnostic instruments can be used in two ways:

1. in a pre-test at the start of a topic or unit to determine students' command of the foundation terms and concepts essential for further work;
2. in a post-test given to those students who did poorly on an in-class test on the topic or unit.

In both cases the teacher can initiate specific remedial procedures before the knowledge gap widens to the point where the student flounders.

Specific instruments in OAIP: Physics have not been identified as diagnostic ones, for what is a diagnostic instrument for one situation may not be so for another. For example, an instrument could function as a diagnostic instrument for Ontario Academic Credit students and as a regular end-of-course achievement instrument for students in Senior Courses.

Constructing a Test

The following hints may be of assistance in the constructing of tests.

1. If more than one type of instrument is used in a test, group instruments of like format together, for example, multiple-choice instruments first, short-answer instruments next, essay questions next, and numerical problems last.
2. The size of published instruments is ideal for making review transparencies. To save paper when making tests, the teacher can photo-reduce instruments by a factor of 64 percent and assemble them as shown on page 45. However, photo-reduction of selected-response instruments involving measured quantities may result in the key's not being among the choices or the key's being different choices than intended. An example illustrating this problem is included on page 45. Photo-reduce instruments for tests, but be on the lookout for this fault.

Instruments Photo-Reduced by a Factor of 64 Percent

1 How many significant digits are there in the number 0.340 050?

(A) 3

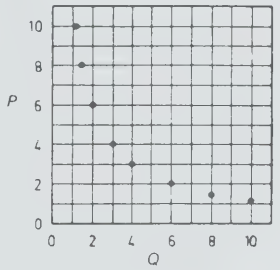
(B) 4

(C) 5

(D) 6

(E) 7

2 The measured values of P and Q as obtained in an experiment were plotted as shown in the figure.



Which one of the following relationships best fits the experimental results?

(A) $P \propto Q$

(B) $P \propto Q^2$

(C) $P \propto \frac{1}{Q}$

(D) $P \propto \frac{1}{Q^2}$

(E) $Q \propto \frac{1}{P^2}$

3 An object is thrown straight up from ground level with a speed of 50 m/s. Its distance above ground 1.0 s after being thrown is

(A) 25 m

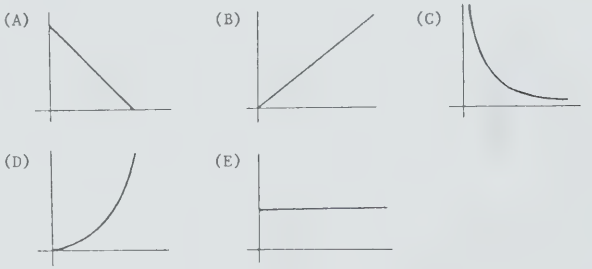
(B) 30 m

(C) 40 m

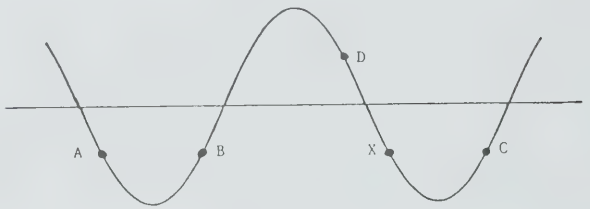
(D) 45 m

(E) 50 m

4 A cart is placed on a frictionless, horizontal surface and is moved by means of elastic bands of identical structure. The mass of the cart may be changed by placing masses on it. From the graphs below, select the one which best describes speed versus time when the cart is pulled by a force which is increasing uniformly with time.



5 The following diagram shows a transverse wave. Use a ruler to take any necessary measurements.



The wavelength of this wave is approximately

(A) 12 cm

(B) 6 cm

(C) 4 cm

(D) 3 cm

(E) 2 cm

The key for the full sized instrument was B. The key for the photo-reduction is C.

3.6 cm — 8.5 cm — 3.6 cm — 8.5 cm — ? cm

Timing

Students should have adequate time to write a test. It is much better for students to have too much time than too little. When students rush through a test, the later instruments usually give very distorted information on student achievement and spoil the reliability of the whole test.

In planning a test the teacher should allow on average at least one-and-a-half minutes per standard multiple-choice instrument and longer for both multiple-response multiple-choice instruments and assertion-reason multiple-choice. About half a minute should be allowed for alternate-response instruments. The length of time allotted for created-response instruments depends on the sophistication and length expected of the answer. The teacher can try allowing one minute for every two scoring points ✓ of the scoring scheme. The time allotted for laboratory-experiment test instruments and laboratory-skill test instruments will also vary with the task.

Aids

Some instruments may require students to make physical measurements on the test paper. Students should be advised to bring a metric ruler and a protractor when these are needed. Other items require the use of trigonometric tables. Students should be provided with these when they are required.

Security of Instruments

The pool is open to the general public and to all educators in Ontario. It is preferred, however, that students not retain copies of the tests administered to them. If students do not retain copies, the teacher can use the instrument again with the assurance that each group of students approaches the tasks as did other groups. If comparisons are to be made from class to class, or from year to year, the teacher must feel sure that one group of students has not had an advantage from having previewed the instruments.

If students retain copies, there is a danger that they may simply confine their studying to memorizing answers to instruments in circulation. This blind memorization is usually done to the exclusion of other more desirable learning activities and often defeats the attempts of the teacher who feels that rote memorization is not the purpose of education.

Sharing in Further Development of the Pool

The instruments presently in the pool and those that remain to be published represent the efforts of knowledgeable and dedicated educators. The collection of instruments published here should be viewed as only the first stage of an ongoing co-operative effort to develop a comprehensive pool of assessment materials for secondary school physics. Teachers using the materials can help by:

1. identifying errors and ambiguities that may exist in the instruments;
2. identifying and providing examples of ways in which instruments can be modified or adapted to address different objectives or to meet the needs of students in courses requiring differing levels of ability;
3. identifying gaps in coverage of topics or instrument types;
4. submitting original instruments that can be edited and screened to fill topic and instrument gaps;
5. suggesting modifications to the instruments, the scoring schemes, or the organization of the materials so that they can be more easily used in the assessment process.

Comments, suggestions, and examples should be forwarded to:

OAIP: Physics Project
Research Branch
Ministry of Education
Mowat Block, Queen's Park
Toronto, Ontario
M7A 1L2

Acknowledgements

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It is impossible to acknowledge the contributions made by the many educators who participated in the development of the pool; the list of all participants is too long. However, the Ministry of Education does wish to acknowledge the specific contributions of the following people who assisted in developing the Senior Division Physics section of the Ontario Assessment Instrument Pool.

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APPENDIX A

STAO CONTENT OBJECTIVES*

CORE TOPICS

Objective No.		
		MEASUREMENT - M
1		1. Express any number in scientific notation (standard form).
2		2. Express experimental measurements with the appropriate number of significant digits (e.g. 2.0 cm instead of 2 cm).
3		3. Express calculations from experimental data to the appropriate number of significant digits (e.g. 3.5 cm x 8.27 cm = 29 cm^2).
4		4. Express all measurements in the appropriate SI units (as outlined in the current edition of the Metric Guide, formerly the Metric Style Guide).
5		5. Realize that the results of experiments in physics are not exact and determine the percent deviation in the final result of a calculation, given the accepted value.
	E+	6. Realize that the results of experiments in physics are not exact, and, for example, be able to:
6		(a) define the terms absolute error, relative error, percentage error;
7		(b) determine the absolute and the relative errors for measurements made in an experiment;
8		(c) determine the absolute and relative error in the final answer when measured quantities are used to calculate the answer.

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* The Science Teachers' Association of Ontario, Senior Division Physics: A Core Curriculum for Grades 11 and 13, STAO Science Resource Centre, Queen's University, Kingston, Ontario, 1977.

\+ Note: the symbol E is used throughout the core topics section to designate those objectives whose achievement through laboratory experiments is highly recommended.

Objective No.

FUNCTIONS - F

E 1. Carry out the following operations, given a table containing experimental data.+

9 (a) Plot the data on a graph;

10 (b) Recognize from the graph whether it is reasonable to assume a linear relationship;

11 (c) If the relationship is linear, write the proportionality statement and the equation;

12 (d) Replot the data to yield a straight line if the relationship is non-linear, and write the proportionality statement and equation of the line;

13 (e) Given a graph, interpolate and extrapolate.

KINEMATICS - K

Motion in a Straight Line - K-MSL

14 E 1. Collect sufficient data from a record of motion (ticker tape, photograph, etc.) and represent the motion graphically (position-time graph or velocity-time graph).

15 2. Given a position-time graph illustrating constant velocity motion, deduce the velocity.

16 3. Given a position-time graph of any motion, deduce the velocity of any instant.

4. Given a velocity-time graph illustrating constant acceleration, deduce:

17 (a) the acceleration of the object;

18 (b) the position of the object at any instant;

19 (c) an analytical relation for acceleration, that is,

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

20 (d) an analytical relation for displacement, that is

$$\Delta\vec{d} = \frac{(\vec{v}_f + \vec{v}_i)\Delta t}{2}$$

and identify situations in which this equation is applicable.

+ Data are limited to linear, power law, inverse relationship, and inverse square relationships.

Objective No.

21 5. Solve problems using the equations in 4 (c) and 4 (d) above and in so doing become familiar with the fact that the preferred units of velocity and acceleration in SI are derived from the metre and second.

Motion in a Plane and Vectors - K-MPV

22 6. (a) Express any position in a plane by the use of a fixed reference point and a vector.

23 (b) Deduce the vector which represents the displacement between any two positions.

24 E (c) Construct a vector equal to the sum of two or more given vectors.

25 (d) Construct a vector equal to the difference between two given vectors.

26 (e) Construct a vector equal to the product of a scalar quantity, or a number, times a vector.

27 (f) Given two positions in a plane and the time to move from one to the other, calculate the average velocity vector

$$\vec{v}_{av} = \frac{\Delta \vec{d}}{\Delta t}$$

28 (g) Given any vector in a plane, use trigonometry or a scale diagram to determine two mutually perpendicular components of the vector.

29 (h) Determine the change in velocity vector and the acceleration vector for the motion of a projectile.

30 (i) Calculate the average vector acceleration for an object moving in a circle at constant speed, expressing the answer in some examples in metres per second squared (m/s^2).

$$\vec{a}_{av} = \frac{\Delta \vec{v}}{\Delta t}$$

DYNAMICS - D

Force and Newton's Laws - D-FNL

31 1. (a) Describe what is meant by the term "force". Identify the vector nature of force and determine the resultant of a system of two or more forces expressed in newtons (see also item 35).

Objective No.		
32	E	(b) Recognize that if no unbalanced (net) force acts on an object, that object will continue in its present state of rest or uniform motion.
33	E	(c) Recognize that when an unbalanced (net) force does act on an object, the object is accelerated in the direction of the force.
34	E	(d) Do an experiment to illustrate the direct relation between the unbalanced (net) force applied to an object and the acceleration it experiences.
35		(e) Define the newton as the unit of force. Given any two of acceleration, mass, or unbalanced (net) force, deduce the third of these variables using the relationship $\vec{a} = \frac{\vec{F}}{m}$
36		(f) State what is meant by the terms inertial mass and gravitational mass.
37		(g) Given a description of a force, state the reaction force.

Centripetal Force and Gravitation - D-CFG

38	E	(h) Use $F = \frac{mv^2}{R}$ and $\vec{F} = -\frac{4\pi^2 m\vec{R}}{T^2}$ to solve circular motion problems.
39		(i) State Kepler's laws of motion.
40		(j) State Newton's Universal Law of Gravitation and use $F = \frac{Gm_1m_2}{R^2}$ to solve problems illustrating the inverse square law $G = 6.670 \times 10^{-11}\ N \cdot m^2 \cdot kg^{-2}$

Impulse and Conservation of Momentum - D-ICM

41	E	2. (a) Define momentum and state the primary SI units of momentum.
42		(b) Solve problems using $\vec{p} = m\vec{v}$ and $\vec{F}\Delta t = m\Delta\vec{v} = \Delta\vec{p}$.
		(c) Apply the principle of conservation of momentum involving the interaction of two or more masses in a:
43		(i) one-dimensional collision or explosion
44		(ii) two-dimensional collision or explosion.

Objective No.

Work and Kinetic Energy - D-WKE

45 E 3. (a) (i) Deduce work as a measure of energy transfer.

46 (ii) Define the joule as the unit of energy and work.

47 (b) Calculate the work done on an object as being equal to the magnitude of the component of the force in the direction of the motion times the displacement.

48 (c) (i) Define power and the SI unit of power, the watt.

49 (ii) Solve problems involving power using the watt as the unit of power, and the watt second as an equivalent form of the joule.

50 (d) Recognize a situation in which the component of a force is perpendicular to the displacement and recognize that no work is done by that component of force.

51 (e) Define kinetic energy as energy due to the motion of the mass of an object.

52 (f) State the relation between work and kinetic energy (that is, when work results only in the acceleration of an object, then the work done is equal to the kinetic energy gained by the object, neglecting friction).

53 (g) State the relation between kinetic energy, mass, and velocity (that is $E_K = \frac{1}{2}mv^2$) and given all but one of those variables, calculate the unknown.

54 (h) Use the principles of conservation of momentum and kinetic energy in a one-dimensional elastic collision to determine the velocities of the two masses after the collision, given their masses and velocities before the collision.

Gravitational Potential Energy - D-GPE

55 4. (a) State the relationship between the change in gravitational potential energy near the surface of the earth and the height of a mass m above the surface ($\Delta U = mg\Delta h$) and solve problems.

56 E (b) Describe the energy conversion occurring in an object falling toward the earth, neglecting friction.

57 (c) Recognize the mutual nature of potential energy (i.e. a property of the system) and discuss gravitational potential energy using the relationship

$$U_G = -\frac{Gm_1m_2}{R}$$

Objective No.

BEHAVIOUR OF LIGHT AND MODELS OF LIGHT - L

Geometric Optics - L-GO

58 1. List the properties of light such as:

(a) transmission through a vacuum;

E (b) linear propagation;

(c) speed of light.

59 E 2. Determine the path taken by a ray of light given the direction of the incident ray and the orientation of the reflecting surface (plane or curved) with respect to the incident ray.

60 E 3. Determine the path taken by a ray of light given the direction of the incident ray, the orientation of the refracting interface, and the index of refraction of the refractive medium.

61 E 4. Recognize that light may be simultaneously reflected and refracted at an interface.

Particle Model of Light - L-PML

62 5. (a) Explain what is meant by the term scientific model.

63 E (b) Describe the particle model of light.

6. Describe the predictions made by the particle model about the following properties of light:

64 (a) reflection;

65 E (b) refraction (Snell's Law: $n = \frac{\sin i}{\sin r}$);

66 (c) propagation through a vacuum;

67 (d) the inverse square law of intensity.

68 7. Explain the difficulties encountered by the particle model such as speed of light in a vacuum and partial reflection and transmission.

Characteristics and Behaviours of Waves - L-CBW

69 E 8. Define or describe the following terms related to the transmission of energy by waves: vibration, frequency, hertz, period, amplitude, wave, periodic wave, transverse wave, longitudinal wave, wavelength, crest, trough, vibrating in phase, universal wave equation.

Objective No.

70 E 9. Solve problems using the universal wave equation ($v = f\lambda$), noting that $f = 1/T$ where frequency is in hertz and the period is in seconds, and that $m \cdot Hz = m.s^{-1} = m/s$.

E 10. Draw a diagram to illustrate how a plane wave in water:

71 (a) reflects from a straight barrier;

72 (b) refracts from deep to shallow water and vice versa;

73 (c) simultaneously reflects and refracts.

74 E 11. Show, by means of sketches, how slit width and wavelength affect the amount of diffraction of water waves, as in a ripple tank, for example.

Interference of Periodic Waves - L-IPW

75 E 12. (a) Construct the resultant pulse given an accurate description or drawing of the two interfering pulses.

76 (b) State the conditions under which standing waves will be produced.

77 (c) Determine the wavelength given a standing wave pattern.

78 (d) Identify areas of constructive and destructive interference in a two-dimensional medium in which two sources are vibrating in phase.

79 (e) Verify the relationship [path length difference = $(n - \frac{1}{2})\lambda$] for destructive interference given the diagram of an interference pattern produced by two point sources.

80 (f) Describe how the pattern in (d) will change if the two sources are made to vibrate with a changing phase.

Wave Model of Light and Interference - L-WML

E 13. Explain the prediction made by the wave model about the following properties of light:

81 (a) reflection;

82 (b) refraction (Snell's Law: $\frac{\sin i}{\sin r} = n = \frac{\lambda_i}{\lambda_r} = \frac{v_i}{v_r}$)

Objective No.		
83		(c) simultaneous reflection and refraction.
84	E	14. (a) Describe the experimental conditions that must be fulfilled in order to observe interference of light predicted by the wave model.
85		(b) Derive the equation $\lambda = \frac{d\Delta x}{L}$ from $\frac{x_n}{L} = \frac{(n - \frac{1}{2})\lambda}{d}$ and use it to solve problems.
86		(c) Determine the wavelength, generally expressed in nanometres (nm), of light by experiment, given a monochromatic light source and a double-slit separation.
87		(d) Describe the pattern produced by a single slit.
88		15. Explain the difficulties encountered by the wave model, such as transmission through a vacuum.

ELECTRICITY AND MAGNETISM - EM

Electric Forces and Charges - EM-EFC

89		1. Recognize that like charges repel and unlike charges attract.
90	E	2. (a) State Coulomb's Law: $F \propto \frac{q_1 q_2}{R^2}$ and hence that the force in newtons is given by the equation: $F = \frac{Kq_1q_2}{R^2}$ where the charges are in coulombs, the distance between them in metres, and $K = 8.988 \times 10^9\ N \cdot m^2 \cdot C^{-2}$
91		(b) Solve problems using the law.
92		(c) Vectorially add electric forces that are coplanar.

Electric Field and Potential - EM-EFP

93	E	3. (a) Define electric force field.
		(b) Describe (with the aid of a diagram) the electric force field:
94		(i) about a single charged metal sphere;
95		(ii) between two oppositely charged parallel metal plates.

Objective No.		
96		4. Write the equation which describes the potential energy stored in a system consisting of two point charges as a function of q_1, q_2, and R, and solve problems using this equation.
97		5. Compare $U_E = \frac{Kq_1q_2}{R}$ and $U_G = \frac{Gm_1m_2}{R}$
98	E	6. Explain the significance of Millikan's experiment.
99	E	7. Describe the motion of electrons in a uniform electric force field.
		Current Electricity and Electromagnetism - EM-CEE
100	E	8. Cite evidence for the fact that electricity can be generated through the transfer of energy from other sources.
101		9. Define current and potential difference and realize that current is stated in amperes (A) and potential difference in volts (V).
102	E	10. State the relationship between the potential difference across the ends of an ohmic conductor and the current through it (Ohm's Law).
103		11. Define the ohm (Ω) as the unit of resistance.
104	E	12. Solve problems involving Ohm's Law, $V = IR$, including examples with resistors in series and examples with resistors in parallel, which illustrate the conservation of energy and charge in simple circuits.
105	E	13. Define the power rating of electrical appliances.
106	E	14. Solve problems involving the cost of electrical energy and apply some of these problems to the wise use of energy.
107	E	15. Describe the magnetic force between two straight parallel conducting wires in which moving electrons constitute a current.
108	E	16. Describe the magnetic force field (magnitude and direction) about conductors in which moving electrons constitute a current (i) in a straight wire (ii) in a single loop (iii) in a helix or coil

Objective No.		
109	E	17. Describe the motion of electrons in a uniform magnetic force field for electrons moving perpendicular to the field.
		Electromagnetic Spectrum - EM-ES
110		18. (a) List the types of radiations that make up the electromagnetic radiation spectrum.
111		(b) Describe the conditions under which an electromagnetic wave is generated and list characteristics common to all electromagnetic waves.
112	E	(c) Recognize emission line spectra and describe how they may be produced.
113		(d) Realize that the line spectrum produced by an atom is a characteristic property of that atom.
		WAVE/PARTICLE DUALITY OF ELECTROMAGNETIC RADIATION AND MATTER - WPD
		Photons - WPD-P
114	E	1. Explain how the photoelectric effect supports the particle theory of light.
115		2. Explain the significance of the interference effects associated with light of extremely low intensity (Taylor's experiment).
116		3. Give an account of Einstein's interpretations of the photoelectric effect ($E_k = hf - B$), where Planck's constant $h = 6.626 \times 10^{-34}$ J·s $= 4.136 \times 10^{-15}$ eV·s.
117		4. Define electron-volt (eV).
118		5. Solve problems involving the relationship $E_k = hf - B$
119		6. Explain the significance of the Compton effect.
120		7. Calculate the momentum of a photon given its frequency or wavelength, $p = \frac{h}{\lambda} = \frac{hf}{c}$.
121		8. Explain under what conditions of the interaction of electromagnetic radiation with matter (i.e. exchange of energy or momentum or both) the particle nature of electromagnetic radiation is predominant and under what conditions the wave nature is predominant.

Objective No.

Matter Waves - WPD-MW

122 E 9. Describe the conditions under which matter exhibits a wave nature.

123 10. Calculate the deBroglie wavelength of a particle given its mass and velocity

$$(\lambda = \frac{h}{mv})$$

124 11. Explain under what conditions of the interaction of elementary particles (electrons, neutrons) with matter (i.e. interaction being the exchange of energy or momentum or both) the particle nature of matter is predominant and under what conditions the wave nature is predominant.

THE ATOM - A

The Rutherford Model - A-RM

125 1. (a) Describe qualitatively Rutherford's experiment.

126 (b) Describe the model of the atom inferred from Rutherford's experiment.

127 (c) Discuss predictions made by Rutherford's classical atomic model that are inconsistent with the observed behaviour of atoms.

Energy Levels - A-EL

128 2. (a) Cite evidence that the energy of atoms increases in discrete steps (Franck-Hertz).

129 (b) Cite evidence that a characteristic set of energy levels exists for each atom.

(c) Given an energy level diagram for a specific element:

130 (i) State the ionization energy of the element.

131 (ii) Determine the energy of photons that could be produced when the atom is excited.

132 (iii) Determine the energies of photons the atom will absorb.

Objective No.		
133	E	3. Verify the equation $E = \frac{13.6}{n^2}$ eV by experimental observation of the spectrum of atomic hydrogen after observing the teacher derive the equation theoretically.

NUCLEAR ENERGY - NE

134		1. (a) Compare the size and density of the nucleus as discovered in the Rutherford experiment with the size and density of the atom.
135		(b) Define atomic number, mass number, and isotope.
136		2. (a) Compare the mass and charge of nucleons with the mass and charge of electrons.
137		(b) Compare qualitatively the range and strength of the nuclear force with the range and strength of the electric force.
138		3. (a) Write the equation for each of alpha, beta, and gamma decay of a nucleus.
139		(b) Compare the mass, charge, energy, and ability to penetrate matter for the products of alpha, beta, and gamma decays.
140		4. Write the equations for a neutron-gamma nuclear reaction and be able to account for the change in the masses and energies of the constituents of the reaction using the equation $E = mc^2$.
141		5. (a) Distinguish between the nuclear fission and nuclear fusion reactions and the environments necessary for their completion.
142		(b) Write the equations for the fusion reactions in the sun and the fission reaction in the CANDU reactor.

OPTIONAL TOPICS

SOUND - S

(Core objectives 27, 45 to 53, 69, 70, 75, 76, 77, and 81 are required for this unit.)

The Nature of Sound - S-NS

143 1. Recognize that the source of all sound is mechanical vibrations.

144 2. Recognize evidence for the transmission of sound by longitudinal waves.

145 3. Describe an experiment to determine the speed of sound in air.

146 4. State the value for the speed of sound in air at 0°C.

147 5. Solve problems using $v = \frac{\Delta d}{\Delta t}$

148 6. Solve problems using $v = f\lambda = \frac{\lambda}{T}$

149 7. Calculate the speed of sound in air at a particular temperature, given that the speed changes by 0.6 m/s for every 1°C temperature change.

150 8. State the location of silent points near a sounding tuning fork.

151 9. Explain the occurrence of silent points near a sounding tuning fork by applying knowledge of how the sound waves are produced in each direction, of how interference occurs, and of the result of interference.

152 10. Explain the interference of sound coming from two identical sources.

Music - S-M

153 11. State that the three main physiological characteristics of musical sounds are pitch, loudness and quality.

154 12. State that the physical factors that respectively determine these characteristics of musical sounds are frequency, intensity, and harmonic content (overtones). Note: The SI unit of frequency is hertz (Hz), which is equivalent to the reciprocal second (s^{-1}).

Objective No.	
	13. Illustrate, with density of air versus distance graphs, the difference between sound of:
155	(a) small and large amplitude;
156	(b) high and low frequency;
157	(c) pure tone and overtones.
158	14. State the conditions necessary for the production of beats.
159	15. Determine the frequency of a tuning fork using a second tuning fork of known frequency and the production of beats.
160	16. Explain how the production of beats can be used to tune a musical instrument (such as a guitar).
161	17. Describe an experiment to illustrate mechanical resonance.
162	18. State the conditions necessary for the production of resonance (mechanical and accoustical).
163, 168	19. (a) Determine the lengths of a closed air column that will resonate with a tuning fork of known frequency.
164, 169	(b) Relate these lengths to the wavelength of the sound causing the resonance.
165, 170	(c) Determine the speed of sound using the information obtained from (a) and (b) above.
166, 171	(d) Construct a diagram to explain 19 (b) in terms of standing waves.
167, 172	20. State the relationship between resonant lengths in a closed air column, fundamentals, overtones, and harmonics.
168-172	21. Do objectives 19 and 20 above for open air columns.
	22. Solve problems on:
173	(a) closed tubes using $L_1 = \frac{1}{4}\lambda$, $L_2 = 3/4\ \lambda$, etc. given resonant length or wavelength (solve for the unknown);
174	(b) open tubes using $L_1 = \frac{1}{2}\lambda$, $L_2 = 2/2\ \lambda$, etc. given resonant length or wavelength (solve for the unknown).

Objective No.

175 23. Solve problems on open or closed tubes using the difference in consecutive resonant lengths = $\frac{1}{2}\lambda$.

24. Explain the operation of

176 (a) a pipe organ

177 (b) a trumpet

in terms of resonance.

178 25. Explain how a vibrating string produces sound.

179 26. Indicate the effect which length of the string, tension on the string, and thickness of the string have on its frequency.

180 27. Explain how a stringed instrument produces sound of different frequencies.

Noise - S-N

181 State that sound intensity is measured in the units of

$$\frac{\text{energy}}{\text{time x area}} = \frac{\text{power}}{\text{area}}$$

182 29. State that the power of ordinary conversation is about 1W.

183 30. Recognize that the power of sounds of medium loudness is small compared to the power of a light bulb.

184 31. Explain that the human ear is very sensitive, as concluded from the comparison of sound and light power generation.

185 32. List approximate intensity levels, in decibels and watts per square metre, for everyday sounds such as (using a reference level of 10^{-12} $W \cdot m^{-2}$):

(a) noise level in an average home (3.2×10^{-9} $W \cdot m^{-2}$ or 35 dB)

(b) the maximum continuous noise level for safety (1.0×10^{-7} $W \cdot m^{-2}$ or 50 dB)

(c) ordinary conversation (1.0×10^{-6} $W \cdot m^{-2}$ or 60 dB)

Objective No.

(d) heavy truck traffic (1.0×10^{-3} $W \cdot m^{-2}$ or 90 dB)

(e) a jet aircraft taking off 60 m away (1.0 $W \cdot m^{-2}$ or 120 dB)

(f) a rock concert (1.0×10^{3} $W \cdot m^{-2}$ or 150 dB)

186 33. Recognize that intensity is measured with a sound-level meter, which converts sound energy into electrical energy.

187 34. Distinguish between the terms occupational noise and non-occupational noise.

188 35. List three examples of occupational noise and list three types of non-occupational noise.

189 36. Recognize that any loud sound may be hazardous to our hearing.

190 37. Recognize that the longer and louder a sound is, the more hazardous it is.

The Ear - S-E

191 38. Draw a schematic diagram of the ear, labelling generally the outer, middle, and inner ear, and labelling specifically the auditory canal, tympanic membrane (ear-drum), ossicles, tuba auditiva, basilar membrane, and helicotrema.

192 39. Describe how the outer and middle ear function.

193 40. Describe the function of the basilar membrane and the helicotrema.

194 41. Describe the range of sensitivity of the average human ear and its threshold of audibility in decibels and watts per square metre for this range.

195 42. Describe the ability of the human ear to distinguish between sounds of different pitch or frequency and to determine the absolute pitch or frequency.

196 43. Solve problems which treat the auditory canal as a resonant column closed at one end.

197 44. Describe environmental factors which could be hazardous to hearing.

Objective No.

ELECTROMAGNETISM - E

(Core objectives 100 to 108 inclusive are required for this unit.)

Magnets - E-M

198 1. Define and describe the following: ferromagnetic; north-seeking pole and south-seeking pole of a bar magnet. (The concepts of North Pole and South Pole are geographic. The so-called North Magnetic Pole of the Earth has the same magnetic properties as the south-seeking pole of a magnet, and the South Magnetic Pole has the same magnetic properties as the north-seeking pole.)

199 2. State the laws of magnetic attraction and repulsion.

200 3. List four characteristics of magnetic field lines: i.e. they have direction and are continuous; the magnetic field strength at a point in space is related to the density of magnetic field lines at that point; the direction of the magnetic field at any point in space is tangent to the magnetic field lines at that point, and in the same direction; they do not intersect (they are by convention directed from N to S outside a bar magnet).

201 4. Use a white printer, print paper, flood lamps, iron filings, and magnets to obtain permanent records of field lines around permanent and electromagnets.

202 5. Sketch the magnetic field lines about a bar magnet, a horseshoe magnet, and simple combinations of magnets. The sketch should show the direction of the magnetic field lines.

Electromagnets - E-E

203 6. Determine either the direction of electron flow in a conductor or the direction of the magnetic field lines about it (given one of the two).

204 7. Determine either the magnetic polarity of a coil or the direction of electron flow through it (given one of the two).

205 8. List four factors which affect the strength of the magnetic field associated with a solenoid (coil) such as current, number of turns per unit length, diameter, core material.

Objective No.	
206	9. Determine the direction a wire will move when placed in a magnetic field and carrying an electron flow, given the direction of electron flow and the direction of the magnetic field lines.
207	10. Determine the direction of electron flow induced by a changing magnetic field given the manner in which the magnetic field is changing.
208	11. Recognize that the size of the induced current depends on the rate of change of the magnetic field about the conductor.
	Applications - E-A
209	12. State the energy conversion carried out in (a) a motor, (b) a generator.
210	13. Draw labelled structural diagrams showing the similarities and differences of the following: D.C. generator, A.C. generator, D.C. motor.
211	14. Determine one of the following for a motor, given the other two: (a) direction of rotation (b) polarity of armature (c) direction of electron flow
212	15. Determine one of the following for a generator, given the other two: (a) direction of rotation (b) polarity of armature (c) direction of electron flow
213	16. Explain orally and in writing the construction and operation of D.C. and A.C. generators and D.C. motors.
214	17. Draw a labelled structural diagram of a step-up and step-down transformer.

Objective No.

215, 216 18. State the equations relating:

(a) N_p, N_s, V_p, and V_s (b) I_p, V_p, I_s, and V_s

where N is the number of turns of wire windings, V is the voltage drop across the windings, I is the current through the windings, and the subscripts p and s respectively refer to primary and secondary winding.

217 19. Solve problems using the relationships developed from item 18.

218 20. Explain the advantage of A.C. over D.C. in the transmission of electrical power.

219 21. Construct an electric motor given the materials and instructions.

220 22. Describe the energy transformations that occur in the production of hydroelectric power.

BASIC ELECTRONICS - BE

(Core objectives 89 and 100 to 104 inclusive are required for this unit.)

The p-n Junction - BE-p-n

221 1. Distinguish between conductors, insulators, and semiconductors.

222 2. Sketch the Bohr model diagrams for germanium and silicon and identify the four valence electrons.

223 3. Sketch the crystal structure of intrinsic germanium and silicon.

224 4. Sketch the crystal structures when either a donor impurity or an acceptor impurity has been added.

225 5. Name two donor impurities and two acceptor impurities.

226 6. Explain the terms: extrinsic, donor, acceptor, doping, n-type semiconductor, p-type semiconductor, hole, majority carrier, minority carrier.

227 7. Describe electron conduction in n-type semiconductor material.

Objective No.	
228	8. Describe hole conduction in p-type semiconductor material.
229	9. Describe and sketch the junction of p-type semiconductor and n-type semiconductor.
230	10. Describe and explain the depletion region and junction field at a p-n junction.
231	11. Describe the effect of a p-n junction on the ability of the semiconductor to conduct electricity.
232	12. Describe and explain the effect of forward biassing a p-n junction - on the depletion region and junction field, and on the ability of the junction to conduct electricity.
233	13. Describe and explain the effect of reverse biassing a p-n junction - on the depletion region and junction field, and on the ability of the junction to conduct electricity.
	The Diode - BE-D
234	14. Sketch the schematic symbol for a semiconductor diode and indicate the direction in which the current flows through it.
235	15. Describe and set up a circuit to gather data to draw the characteristic curve of a semiconductor diode.
236	16. Describe and demonstrate (using an oscilloscope) how a semiconductor diode can be used to rectify an alternating current.
	The MOSFET Transistor - BE-MT
237	17. Describe a MOSFET (Metal Oxide Semiconductor Field Effect Transistor) and sketch a labelled diagram thereof.
238	18. Sketch the symbols of an n-channel and p-channel MOSFET.
239	19. Define drain current.
240	20. Describe and set up a circuit to gather data to plot characteristic curves (I_d vs. V_{ds} for various gate voltages) for a transistor in the common drain configuration.

Objective No.

241 21. Demonstrate an understanding of the following quantities and their respective symbols:

- drain-source voltage V_{ds}
- gate-source voltage V_{gs}
- drain-current I_d

242 22. Describe and demonstrate how a transistor can be used as an amplifier. The student should be able to draw a simple schematic.

The Zener Diode - BE-ZD

243 23. Describe and demonstrate the zener effect with a zener diode.

244 24. Draw the symbol for a zener diode and indicate the direction of the zener current through it.

245 25. Set up an experiment and gather data to plot a characteristic curve (I vs. V) for a zener diode.

246 26. Plot a characteristic curve for a zener diode and explain its shape.

247 27. Explain what is happening in a zener breakdown and why the current must be carefully controlled.

248 28. State one use for a zener diode.

249 29. Set up a simple power supply which uses a zener diode as a voltage regulator; observe and describe the output with change in load resistance using an oscilloscope and a voltmeter.

250 30. Draw schematic diagrams for the circuits used in the procedures in items 25 and 29.

251 31. List five other semiconductor devices and state a function for each. Devices include:

(a) diac
(b) triac
(c) thermistor
(d) tunnel diode
(e) photo-sensitive diode
(f) photo-sensitive resistor
(g) photo-sensitive transistor
(h) junction transistor
(i) silicon controlled rectifier

Objective No.

RAY OR GEOMETRIC OPTICS - GO

(Core objectives 81, 82 and 83 are required for this unit.)

Sources and Travel - GO-ST

252 1. Define or state briefly what is meant by a ray of light.

253 2. Give examples of luminous and non-luminous objects.

254 3. State the difference between 'incandescent' and 'nonincandescent' light sources and give two examples of each.

255 4. Describe briefly what is meant by the terms transparent, translucent, and opaque and give examples of each.

256 5. State what is meant by rectilinear propagation and give evidence by referring to shadows formed by point sources.

257 6. Draw a diagram showing the formation of shadows using a large source and labelling the umbra and penumbra.

258 7. Draw a ray diagram showing how a pinhole camera forms an image and describe the image as real, inverted, and laterally reversed.

259 8. Describe in detail one method of measuring the speed of light.

260 9. Describe what is meant by a light year.

261 10. Use a protractor to measure angles to the nearest degree.

Reflection - GO-R

262 11. Define or describe briefly each of the following as they apply to plane mirrors: incident ray, reflected ray, normal, angle of incidence, angle of reflection.

Objective No.	
263	12. State the following laws of reflection: (a) the angle of incidence equals the angle of reflection; (b) the incident ray, the reflected ray, and the normal are all in the same plane.
264	13. Locate the image of an object in a plane mirror.
265	14. Describe the image in a plane mirror as virtual and erect, with the plane of symmetry the plane of the mirror.
266	15. Draw a ray diagram to show how the eye sees an object in a plane mirror.
267	16. Give at least two practical applications of plane mirrors placed at right angles to each other.
268	17. Draw a ray diagram to show how a periscope can be constructed from plane mirrors.
269	18. Distinguish between plane mirrors, convex (diverging) mirrors, and concave (converging) mirrors.
270	19. Draw and label diagrams of both types of spherical mirrors including the following: vertex, focal point, centre of curvature, principal axis, focal length, radius of curvature.
271	20. Work with the relationship $R = 2f$ as it pertains to spherical mirrors.
272	21. Describe how the focal lengths can be obtained for both types of spherical (circular) mirrors by means of a ray optics kit.
273	22. Describe at least two other experimental methods by which the focal length of a spherical concave mirror can be determined.
274	23. Draw ray diagrams to show how spherical mirrors form images.
275	24. Discuss the images formed by plane and spherical mirrors under the headings type, attitude, and magnification.
276	25. Explain briefly why image quality of parabolic mirrors is superior to that of spherical mirrors.

Objective No.

277 26. Draw ray diagrams to show how each of the following operates:

(a) beauty or shaving mirror (concave)

(b) store surveillance mirror (convex)

Refraction - GO-Rfra

278 27. Define or describe briefly what is meant by each of the following: refraction, angle of refraction, index of refraction.

279 28. Determine experimentally the index of refraction of a semi-circular or rectangular transparent block.

29. Describe by means of a diagram the apparent change in position of an object due to refraction in each of the following:

280 (a) a coin at the bottom of a glass filled with water;

281 (b) mirages;

280 (c) fish in water as viewed by a fisherman on the shore;

282 (d) fisherman on bank as viewed by fish in water.

283 30. State the following laws of refraction:

(a) When a ray of light passes obliquely from one medium into another of greater index of refraction, it is refracted towards the normal.

(b) When a ray of light passes obliquely from one medium into another of lesser index of refraction, it is refracted away from the normal.

(c) The incident ray, the refracted ray, the reflected ray, and the normal are all in the same plane.

284 31. Describe qualitatively how a ray refracts as it passes through substances of different indices of refraction.

285 32. Use the formula $n_M = \frac{\sin \theta_A}{\sin \theta_M}$ to calculate one of the following, given the other two:

(a) angle of incidence;

(b) angle of refraction;

Objective No.	
	(c) index of refraction of the medium n_M where θ_A is the angle in air and θ_M is the angle in the medium.
286	33. Describe briefly what is meant by total internal reflection.
287	34. Calculate the critical angle for a substance of known index of refraction.
	35. Illustrate how rays travel through:
288	(a) right-angled prisms;
289	(b) optical fibres.
290	36. Discuss the concept of total internal reflection as it applies to each of the following: periscopes, prism binoculars, sparkle of diamonds, and fibrescopes.
291	37. Accurately draw the path of a ray as it passes through any transparent material of known index of refraction and whose boundaries are straight lines.
292	38. Sketch a diagram showing how a beam of white light is separated into colours of the spectrum by means of a prism.
293	39. Draw and label diagrams for both convex (converging) and concave (diverging) lenses including the following: axis of symmetry, focal point, focal length, optical centre.
294	40. Describe how the focal lengths can be determined for both concave and convex lenses by means of a ray optics kit.
295	41. Describe at least two other experimental methods by which the focal length of a convex lens can be determined.
296	42. Draw ray diagrams to show how lenses form images.
297	43. Discuss the images formed by lenses under the headings type, attitude, and magnification.
298	44. State the similarities and differences in the functions and operation of the eye and the camera.

Objective No.	
	Optical Instruments - GO-OI
299	45. Show by means of a ray diagram how a single lens can be used to illustrate the principle involved in each of the following:
	(a) magnifying glass;
	(b) camera;
	(c) eye;
	(d) slide projector.
300	46. Draw diagrams to show both a nearsighted and a far-sighted eye.
301	47. By means of a diagram, show how lenses are used to correct for nearsightedness and farsightedness.
	48. Draw labelled diagrams showing the relative positions of lenses in each of the following:
302, 305	(a) compound microscope;
303, 306	(b) refracting telescope (Kepler's - 2 convex lenses);
304, 307	(c) Galilean telescope (opera glasses - one convex and one concave lens).
305 - 307	49. Draw ray diagrams for each of the optical instruments listed in 48.
308	50. Discuss briefly the relative advantages of refracting and reflecting telescopes.
	COLOUR - C
	(Core objective 110 is required for this unit.)
	The Spectrum - C-S
	1. Perform or describe experiments to show:
309	(a) the formation of the colours of the spectrum from white light by a prism.
310	(b) that the spectral colours are elementary; i.e. a complete spectrum cannot be produced by a second prism from an isolated part of the spectrum produced by the first prism, and therefore spectral colours are not mixtures of other colours.

Objective No.	
311	(c) the recomposition of white light from the colours of the spectrum by an inverted prism or a converging mirror.
312	(d) the presence of infrared radiation in the spectrum produced by sunlight.
313	(e) the presence of ultraviolet radiation in the spectrum produced by sunlight.
314	2. Define the terms angle of deviation and dispersion in reference to the above experiments.
315	3. Identify the principal colours of the visible spectrum (i.e. red, orange, yellow, green, blue, violet).
316	4. Conclude, by observing that in the production of the visible spectrum red is refracted least and violet refracted most, that different colours have different refractive indices for the same (optically dense) medium.
317	5. Describe how primary and secondary rainbows are produced and seen by an observer.
	Colour and Colour-Mixing - C-M
318	6. Perform or describe experiments to show the results of using two and three additive primary colours, e.g. red, blue, green (coloured lights or rapidly rotating colour discs).
319	7. Identify the subtractive primary colours formed in (6) and demonstrate that these result from subtracting an additive primary from white light. Thus white - blue = yellow white - green = magenta white - red = cyan
320	8. Perform or describe experiments to show the results of combining two and three substractive primary colours.
321	9. Distinguish between additive and subtractive methods of colour mixing (not to be confused with additive and subtractive primary colours).
322	10. Identify pairs of complementary colours and state the results when these are combined additively and subtractively.

Objective No.	
323	11. Explain the results observed in (5) to (9) in terms of spectrum analysis of colours involved.
324	12. Perform or describe simple experiments to demonstrate that the colours (black and white considered 'colours' in this context) of natural objects are the result of selective transmission, absorption, and reflection of various colours.
325	13. Describe the appearance of coloured objects in light of various colours.
326	14. Describe the results obtained when artists' primaries (magenta, yellow, and cyan) are mixed and explain the results in terms of reflection and absorption of light.
327	15. Name several applications of colour theory to daily living, and giving, where appropriate, explanations of how the principles of colour theory are applied.

e.g. Colour TV (additive primaries)
Blueing and brighteners (additive complementary colours)
Adding manganese to green glass to produce colourless glass (additive complementary colours)
Colour film (subtractive primaries)
Photographic filters (absorption)
Colourprinting ('4-colour') (subtractive primaries plus black)
Scattering of white light by the atmosphere and by colloidal dispersions (absorption, selective transmission, and reflection)
Chromatic aberration of lenses and its correction
Colour coding of products
Use of colour to promote safety
Colour packaging and advertising
Principles of using colour in decorating, designing clothing, etc.

Colour Vision - C-V

328	16. Draw a labelled diagram showing the principal structures of the human eye.
329	17. Describe the functions of the principal structures of the human eye with emphasis on those structures involved in colour vision.

Objective No.	
330	18. State the principal postulates of the Young-Helmholz 3-colour theory of colour vision and cite experimental evidence supporting this theory.
331	19. State experimental evidence which is not accounted for by the Young-Helmholz theory of colour vision.
332	20. Name, or describe the postulates of, alternative theories of colour vision such as those of Hering and Land.
333	21. State what is meant by colour-blindness and identify the kinds of colour blindness found in human vision.
334	22. Explain the occurrence of human colour blindness in terms of one or more theories of colour vision.
335	23. Describe how colour blindness may be detected.
336	24. Describe the prevalence of colour blindness and its effect upon the daily life of persons afflicted with this condition.
	Infrared and Ultraviolet Radiation - C-I&UV
337	25. State the properties of infrared radiation and list several applications of infrared, identifying those properties which are relevant to each application; e.g. drying of automotile finishes, medical uses, greenhouses and farm applications, solar heating, infrared photography.
338	26. State the properties of ultraviolet radiation and list several applications of ultraviolet, identifying those properties which are relevant to each application: e.g. sterilization of water or milk, production of vitamin D in the human body, suntanning, fluorescent paints and 'black light' posters, 'invisible ink', fingerprint powder.
339	27. State possible dangers of exposure to ultraviolet radiation and preventative measures that can be taken to counteract such dangers: e.g. sunburn, damage to eyesight (looking directly at sunlight, electric arc welding, etc.).

Objective No.

FLUIDS - F1

(Core objectives 31 to 35, 37, 45 to 53, 55, and 56 are required for this unit.)

Fluids at Rest - F1-R

340 1. Define pressure.

341 2. Define pascal as the unit of pressure.

342 3. State the force of gravity exerted on any given mass.

343 4. State Pascal's Law (i.e. neglecting the force of gravity acting on the fluid itself, the pressure in a fluid at rest is the same everywhere).

344 5. Discuss the operation of a hydraulic cylinder.

345 6. Define density and state the preferred SI unit of density.

346 7. Show experimentally that in the presence of gravity the pressure in a fluid increases with depth.

347 8. State what is meant by 'atmospheric pressure'.

348 9. State what is meant by 'gauge pressure'.

349 10. Describe instruments used to measure pressure such as a manometer (absolute pressure) and a Bourdon gauge (gauge pressure).

350 11. Describe what is meant by 'buoyant force'.

351 12. Show experimentally that the buoyant force exerted by a fluid on an object is equal in magnitude to the force of gravity acting on the fluid displaced by the object (Archimedes' Principle).

352 13. Solve single-concept problems dealing with items (7) and (12).

353 14. Describe two mechanisms used by fish to adjust their depth in water (i.e. swim bladder and porous bones).

354 15. Describe what is meant by the concepts of 'cohesion' and 'adhesion'.

Objective No.	
355	16. Describe what is meant by 'surface tension'.
356, 358	17. Explain why some liquids rise in a vertical capillary open at one end and why some liquids are depressed in such a capillary.
357, 359	18. Define the 'bulk modulus' and state its unit of measure (the pascal), and its reciprocal the 'compressibility', which is measured in reciprocal pascals (Pa^{-1}).
358, 359	19. Solve single-concept problems dealing with items (17) and (18).
	Fluids in Motion - Fl-M
360	20. Describe the concept of viscosity for fluids in motion which can exert forces parallel to a surface.
361	21. Solve single-concept problems dealing with item (20).
362	22. Develop Bernoulli's theorem for an incompressible fluid as an example of conservation of energy in a closed system, neglecting effects of viscosity.
363	23. Use Bernoulli's theorem to explain the action of such devices as the venturi, the automobile carburetor, the jet pump, atomizers, and paint sprayers.
364	24. Use Newton's Second Law to explain the lift provided an airfoil moving in a fluid (air), the lift given a ski jumper, and the lift given an individual remaining afloat by treading water. (Bernoulli's theorem is not the correct explanation. Refer to the article "Bernoulli and Newton on Fluid Mechanics" by N.F. Smith, The Physics Teacher, Nov. 1972, p. 451.)
365	25. Describe what is meant by turbulent flow.
366	26. Explain qualitatively the behaviour of a moving spinning baseball or golfball in terms of turbulent flow and exchange of energy between the object and its surroundings.

Objective No.

THERMAL EFFECTS - T

(Core objectives 45 to 53, 55, and 56 are required for this unit.)

Temperature - T-T

367 1. Describe the temperature of a body as proportional to the average translational kinetic energy of the atoms or molecules of which the body is composed.

368 2. Define the Kelvin and Celsius temperature scales including the bases for establishing these scales and the conversion from one to the other.

Heat - T-H

369 3. Describe heat as transferred energy between a body and its surroundings as a result of temperature differences.

370 4. Distinguish between heat (transferred energy) and temperature (average translational kinetic energy).

Thermal Expansion - T-E

371 5. Show experimentally the phenomena of thermal expansion in solids, liquids, and gases.

372 6. Solve single-concept problems involving expansion.

373 7. Discuss the abnormal expansion of water.

Calorimetry - T-C

374 8. Describe how quantities of heat are measured indirectly by the effects produced by heat, as, for example, by the temperature change of a known mass of water.

375 9. Define the SI unit used in the measurement of heat (joule) and its equivalence to mechanical energy. (If still required, relate the joule to former units such as the calorie.)

376 10. Discuss the concept of specific heat capacity as characteristic of the material of which the body is composed.

Objective No.	
377	11. Define the specific heat capacity of matter as the quantity of heat per unit mass per unit temperature change.
378	12. Define specific heat of a body of matter as the ratio of the heat capacity of that matter to the heat capacity of water.
379	13. Develop a proficiency in the laboratory in the measurement of heat and temperature.
	Evaporation - T-E
380	14. Describe the concept of evaporation.
381	15. Define specific latent heat of evaporation.
382	16. Solve single-concept problems on item (15).
383	17. Discuss in general terms the process by which the human body regulates its temperature and the exchange of heat with its surroundings.
	First Law of Thermodynamics - T-L
384	18. Discuss the first law of thermodynamics as an example of conservation of energy.
	STATICS - ST
	(Core objectives 22 to 24, 31 to 35, and 45 to 47 are required for this unit.)
	Torque and Equilibrium - ST-TE
385	1. Describe the moment or torque of a force about a point as the product of the force and the perpendicular distance from the point to the line of action of the force, and state the SI unit of moment or torque.
386	2. State the conditions for equilibrium of a body: i.e. the sum of the clockwise moments and of the counter-clockwise moments about any point in the body must be numerically equal (rotational equilibrium), and the sum of the forces acting on the body in any one direction must equal the sum of the forces acting on the body in the opposite direction (translational equilibrium). (Use only mutually perpendicular or parallel forces acting on a body.)

387 3. Define what is meant by 'centre of gravity', i.e. the point at which the force of gravity of an object can be considered to act.

388 4. Solve problems on static equilibrium.

Machines - ST-M

389 5. Describe what is meant by the term 'machine', i.e. in terms of a device generally used to transfer or transform energy.

390 6. Define 'actual mechanical advantage' as the ratio of the output force overcome by the machine to the input force applied to the machine.

391 7. Define 'ideal mechanical advantage' as the ratio of the input displacement through which the input force applied to the machine acts, to the output displacement through which the output force overcome by the machine is moved.

392 8. Define the efficiency of any machine as the ratio of the work output to the work input or the ratio of actual mechanical advantage to ideal mechanical advantage.

393 9. Discuss the properties of six simple machines: i.e. the lever, the pulley, the wheel and the axle, the inclined plane, the wedge, and the screw.

394 10. Show experimentally the way in which the six simple machines discussed in item (9) transfer energy.

395 11. Solve simple problems dealing with items (6) to (9).

396 12. Describe examples of the six simple machines referred to in item (9), or combinations thereof, in practical use by man.

RADIOACTIVITY AND RADIATION EXPOSURE - R

(Core objectives 45 to 53, 89, 117, 134, 135, and 138 are required for this unit.)

Radioactivity - R-R

397 1. Recognize the symbol ${}^{A}_{Z}N$ where N represents any nucleus, A is the number of nucleons in N, and Z is the number of protons in N.

Objective No.	
398	2. Define isotope, isotone, and isobar.
399	3. Describe radioactive decay by beta emission.
400	4. Describe the properties of beta radiation.
401	5. Describe radioactive decay by gamma emission.
402	6. Describe the properties of gamma radiation.
403	7. Describe how X-radiation originates.
404	8. Describe the properties of X-radiation.
405	9. Distinguish between gamma radiation and X-radiation in terms of source only.
406	10. Describe radioactive decay by alpha emission.
407	11. Describe the properties of alpha radiation.
408	12. Write equations for radioactive decay in symbolic form.
409	13. Describe what is meant by 'activity'.
410	14. Define the becquerel (Bq), and express it in terms of a second (1 Bq = 1 s^{-1}, or 1 disintegration per second).
411	15. Define half-life as the time for one-half of a specified isotope in a particular sample to decay.
412	16. Plot a graph of 'percent of nuclei present' versus half-life (i.e. 100% at 0 half-life).
413	17. Use the graph plotted in item (16) to determine the activity of a particular nucleus at a specified time (i.e. equivalent number of half-lives) given the activity at an earlier specified time and the half-life.
	Radiation Exposure - R-RE
414	18. Identify and discuss the two main sources of radiation to which man is exposed: the Earth (natural radioactivity) and the sun (proton 'wind'), and the main man-made source (medical and dental applications of X-radiation).

Objective No.	
415	19. Define the SI radiation units for exposure (C/kg), absorbed dose (gray, where 1 Gy = 1 J/kg), and dose equivalent (rem).
416	20. State the quality factor (QF) for 200-250 keV X-radiation, gamma radiation, beta radiation, electrons, thermal neutrons, fast neutrons, protons, alpha radiation, and heavy recoil nuclei.
417	21. Determine the dose equivalent from the absorbed dose using QF: i.e. dose equivalent (rem) = QF x absorbed dose (Gy) x 10^2.
418	22. Define the maximum permissible dose equivalent (MPD) as that dose of radiation, which if received over a 50-year working lifetime is not expected to result in manifest radiation injury.
419	23. State the MPD in rem/a for occupational and non-occupational exposure for categories (a) whole body, gonads, bone marrow, (b) bone, skin, thyroid, (c) any tissue of hands, forearms, feet, and ankles, and (d) other single organs or tissues.
420	24. Distinguish between the four general categories of plots of radiation response versus radiation dose (i.e. linear, non-threshold; linear, threshold; non-linear, non-threshold; and non-linear, threshold).
421	25. Give examples (e.g. death, skin erythema, loss of hair, leukemia, genetic damage, sterility, transient blood changes, congenital abnormalities) for each of the categories in item (24).

ENERGY SOURCES AND CONSERVATION - ES

(Core objectives 43 to 45, 100 to 106, 141, and 142 are required for this unit.)

Energy Sources - ES-S

422	1. List seven energy sources, e.g. the sun, wind, tides, atomic energy, heat from the Earth (geothermal energy), mechanical energy (Niagara Falls), fossil fuels (oil and coal).
423	2. Compare the structure of a solar heated home to the structure of a conventionally heated home.

Objective No.	
424	3. Show how the greenhouse effect can be used in solar homes.
425	4. State the criteria on which personal and collective decisions on energy sources should be made (e.g. Will the source be used up? What effects will be produced on the environment? How much of this type of energy is readily available? What are the dangers of using this kind of energy? How much do we need?).
426	5. Recognize that all energy resources come from the environment and all energy used eventually returns to the environment (although not necessarily in a useful or harmless form). Thus energy use issues are directly related to environmental issues.
	Energy Conservation - ES-C
427	6. State why we should conserve energy (i.e. to reduce environmental problems and to guarantee energy for the future).
428	7. Define the following energy units: the joule, the kilojoule, the kilowatt hour.
429	8. Verify a public utilities bill to justify the cost of each component of the bill.
105	9. Define the power rating of electrical appliances. (This objective has been previously studied in the grade 11 core.)
106	10. Solve problems involving the cost of electrical energy. (This objective has been previously studied in the grade 11 core.)
	11. Make a list of ways of conserving energy in
430	(a) home heating;
431	(b) home appliances;
432	(c) the automobile;
433	(d) housing construction;
434	(e) industry (including schools);
435	(f) agriculture;
436	(g) commerce.

Objective No.	
437	12. Discuss critically an energy conservation proposal in the areas mentioned in objective (11) above.
438	13. Recognize that garbage (such as green garbage bags and potato peels) represents energy too.
439	14. Identify overpackaging, disposable items, and excessive buying as energy problems.
	HISTORICAL PERSPECTIVE - ASTRONOMY - HA
440	1. Discuss the role of astronomy as a science in the life of early man, i.e. the need to observe and understand the sun's motion, seasons, the moon's motion, tides, calendars, etc.
441	2. Discuss the role of astronomy and religion in the life of early man in terms of giving examples and suggesting reasons for behaviour, i.e. worshipping the sun and the moon, connecting the star Sirius with the Nile floods, etc.
	The Universe - HA-U
442	3. Perform simple experiments or make observations to establish a picture of the universe as viewed from earth. For example: (a) The Sun - apparent motion, usefulness of shadows. (b) Stars - apparent motion, constellations. (c) Moon - apparent motion. (d) Eclipses - how produced, how used by priests to obtain political power. (e) Planets - apparent motion, how compared to other stars, motion of outer planets compared to that of inner planets.
443	4. Explain how time was measured using the sun and moon, i.e. day, month, seasons, year.
444	5. Explain what is meant by Ecliptic and Zodiac.
445	6. List the three driving motives of early astronomy as being: (a) practical use of clock, calendar, and compass (i.e. Babylonians, Egyptians).

Objective No.

(b) magic to impress people; and astrology to predict the fates and good and bad fortune.

(c) pure scientific interest.

Greek Scientists - HA-GS

446 7. Discuss the contribution of early Greek scientists to astronomy, such as contributions made by Thales, Pythagoras, Philolaus, Socrates, Plato, Eudoxus, Aristotle, Aristarchus, Eratosthenes, and Ptolemy. (Students should develop an appreciation of how each of the above scientists influenced the thinking of others and how much they depended on logical reasoning and/or experiment.)

447 8. Explain why the Ptolemaic picture of the universe was so widely accepted for so long: i.e. support from observations, man's sense of own importance, lack of knowledge of how objects would stay on a spinning earth.

448 9. Indicate the difficulties of the Ptolemaic theory: i.e. the sophisticated mathematics required to predict planetary motions, philosophic difficulties.

Copernicus and Brahe - HA-C&B

449 10. Briefly describe the Copernican theory of the universe.

450 11. Explain how Copernicus accounted for the epicycloids of Mars, Jupiter, and Saturn.

451 12. Explain how Copernicus estimated and plotted orbits for the planets.

452 13. Discuss why Copernicus' theory was rejected by the Church and his book De Revolution Orbium Coelestium was placed on the list of forbidden books by the Church.

453 14. Give a brief account of events leading to Tycho Brahe's becoming the foremost man of science in Europe: i.e. how he became interested in astronomy, the instruments he constructed to increase accuracy of observation, his being attracted to Denmark where he built an observatory, etc.

454 15. List the events which resulted in Tycho Brahe's leaving Denmark.

Objective No.	
455	16. Indicate the major contributions Tycho Brahe made to astronomy.
	Kepler - HA-K
456	17. Discuss Kepler's attempts to account for planetary orbits in terms of geometric figures.
457	18. Discuss how Kepler's investigation of the motion of Mars produced a discrepancy of 8/60 of a degree with Tycho Brahe's observations and how this resulted in Kepler's abandoning his theory of circular orbits.
458	19. List Kepler's three laws and explain how he arrived at them.
	Galileo - HA-G
459	20. Briefly give an account of the major contributions made by Galileo to the study of astronomy.
460	21. Briefly discuss Galileo's family background and how he was able to pursue his study of astronomy.
461	22. Discuss two thought experiments described by Galileo to describe motion.
462	23. Explain how Galileo's telescope resulted in discoveries which led Galileo to support the Copernican theory.
463	24. Discuss circumstances leading to Galileo's being ordered by the Church not to defend the Copernican theory, to his being given permission to write a noncommital book explaining the arguments on both sides between Copernicus and Ptolemy, and to his being imprisoned for his belief.
	Newton and Beyond - HA-N
464	25. Give a brief account of Isaac Newton's early life and events leading to his contributions to science.
465	26. Briefly describe how Newton first suggested an inverse square law to help him describe how planetary motion could be accounted for according to Kepler's three laws.
466	27. State Newton's three laws of motion.

Objective No.	
467	28. Perform simple calculations involving Newton's three laws of motion.
468	29. Show how Newton's second law was used in the form $F = M \frac{V^2}{R}$ when applied to planetary motion.
469	30. Solve simple problems based on the equation $F = M \frac{V^2}{R}$.
470	31. Discuss the events that made it necessary for Newton to develop calculus.
471	32. Discuss what Newton meant by 'gravity'.
472	33. State Newton's Universal Law of Gravitation.
473	34. Use Newton's laws to account for or derive Kepler's three laws.
474	35. Show how the mass of the sun could be determined in terms of the mass of the Earth using Newton's law.
475	36. Describe how Newton accounted for precession of the equinoxes.
476	37. Discuss how Newton accounted for the variations in the moon's motion in its orbit.
477	38. Explain how tides on earth are accounted for.
478	39. Describe comets and explain how their orbits can be predicted.
479	40. Discuss how artificial satellites can be put into orbit, according to Newton.
480	41. Discuss the events leading to the discovery of Neptune, i.e. the observations of small deviations in the orbit of Uranus from what would be predicted by applying Newton's Laws.
481	42. Give one example of how guessing played a major role in Newton's discoveries.
482	43. Show the significance of the Cavendish experiment in determining the constant in the universal law of gravitation.
483	44. Prepare a chart to show how the work and lives of the scientists involved in the study of astronomy overlap or build on each other.

APPENDIX B

KLOPFER BEHAVIOUR CATEGORIES*

A. KNOWLEDGE AND COMPREHENSION

A.1 Knowledge of specific facts

A.2 Knowledge of scientific terminology

A.3 Knowledge of concepts of science

A.4 Knowledge of conventions

A.5 Knowledge of trends and sequences

A.6 Knowledge of classifications, categories and criteria

A.7 Knowledge of scientific techniques and procedures

A.8 Knowledge of scientific principles and laws

A.9 Knowledge of theories or major conceptual schemes

A.10 Identification of a fact, concept, procedure, classification scheme, or theory in a new context

A.11 Translation of a fact, term, concept, trend, principle, or theory presented in one symbolic form to another symbolic form

B. PROCESSES OF SCIENTIFIC INQUIRY I: OBSERVING AND MEASURING

B.1 Observation of objects and phenomena

B.2 Description of observations using appropriate language

B.3 Measurement of objects and changes

B.4 Selection of appropriate measuring instruments

B.5 Estimation of measurements and recognition of limits in accuracy of measurements

C. PROCESSES OF SCIENTIFIC INQUIRY II: SEEING A PROBLEM AND SEEKING WAYS TO SOLVE IT

C.1 Recognition of a problem

C.2 Formulation of a working hypothesis

C.3 Selection of suitable tests of a hypothesis

C.4 Design of appropriate procedures for performing experimental tests

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* Klopfer, L.E., Evaluation of Learning in Science. In Bloom, B.S., Hastings, J.T., and Madaus, G.F. Handbook of Formative and Summative Evaluation of Student Learning. New York: McGraw-Hill, 1971.

D. PROCESSES OF SCIENTIFIC INQUIRY III: INTERPRETING DATA AND FORMULATING GENERALIZATIONS

D.1 Processing of experimental data

D.2 Presentation of data in the form of functional relationships

D.3 Interpretation of experimental data and observations

D.4 Extrapolation, when warranted, of functional relationships beyond actual observations, and interpolation between observed points

D.5 Evaluation of hypothesis under test in the light of the experimental data obtained

D.6 Formulation of appropriate generalizations (empirical laws or principles) that are warranted by the relationships found

E. PROCESSES OF SCIENTIFIC INQUIRY IV: BUILDING, TESTING, AND REVISING A THEORETICAL MODEL

E.1 Recognition of need for a theoretical model to relate different phenomena and empirical laws or principles

E.2 Formulation of a theoretical model to accommodate the known phenomena and principles

E.3 Specification of phenomena and principles that are satisfied or explained by a theoretical model

E.4 Deducation of new hypotheses from a theoretical model to direct observations and experiments for testing it

E.5 Interpretation and evaluation of the results of experiments to test a theoretical model

E.6 Formulation, when warranted by new observations or interpretations, of a revised, refined, or extended theoretical model

F. APPLICATION OF SCIENTIFIC KNOWLEDGE AND METHODS

F.1 To new problems in the same field of science

F.2 To new problems in a different field of science

F.3 To problems outside of science (including technology)

G. MANUAL SKILLS

G.1 Development of skills in using common laboratory equipment

G.2 Performance of common laboratory techniques with care and safety

H. ATTITUDES AND INTERESTS

H.1 Manifestation of favorable attitudes toward science and scientists

H.2 Acceptance of scientific inquiry as a way of thought

H.3 Adoption of habits of thought which ideally characterize scientists when engaged in inquiry ("scientific attitudes")

H.4 Enjoyment of science learning experiences

H.5 Development of interests in science and science-related activities

H.6 Development of interest (for some students) in pursuing a career in science or in science-related work

I. ORIENTATION

I.1 Distinction between various types of statements in science (e.g. observation, interpretation, law, theory) and their relationship to one another

I.2 Recognition of the limitations of scientific explanation and of the influence of scientific inquiry on general philosophy

I.3 Historical Perspective: Recognition that the past, present, and future development of science is a product of its own history and a reflection of the general culture of its time

I.4 Realization of the relationships existing among scientific progress, technical achievements, and economic development

I.5 Awareness of the social and moral implications of scientific inquiry and its results for the individual, community, nation, and the world